# *The Nm1 (Newton Microscopes): Part 2 of 2*

## *An in-depth examination and comparison to other folded-optics designs*

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Figure 1. Newton microscope in its foam lined plastic transport case as received

## *Introduction*

The Newton Microscope is really three (perhaps one may say six) microscopes: the Nm1 - 400, Nm1 - 400 XY, Nm1 - 600, Nm1 - 600 XY, NM1 - 1000, and the Nm1 - 1000 XY. The primary differences are the magnifications available, and the presence or absence of a mechanical stage. Fig. 2 provides a close-up view of the Nm1 - 1000 with and without mechanical stage. On the Newton Microscope website, the microscopes are sometimes shown as $Nm^1$ rather than simply Nm1. Nm1 seems the more popular designation, and is the one used here.

At the time of this publication, the Newton Microscope site had not yet had a chance to post photographs of the Nm1 - 400 and Nm1 – 600 XY in their sales illustrations, and instead used pictures of the Nm1 - 1000, as a stand-in. All Nm1s come with an external USB power cable and a "Rugged foam lined carry case". A picture of the inside of this case holding a Newton Nm1 - 1000 XY and accessories is shown in Fig. 1.

The Nm1 - 400, contains a 10x eyepiece and 2 objectives, 10x and 40x. The Nm1 - 600 XY has an additional 60x objective, and the Nm1 – 1000 XY has a 100x oil immersion objective in place of the 60x objective. If an XY stage is present, models contain an XY suffix after their designation. Thus, we have the Nm1 - 400 XY, the NM1 - 600 XY, and the NM1 - 1000 XY.

In December 2013, the Newton Microscopes prices were listed as Nm1 - 400 £399.95, Nm1 - 600 XY, £579.95, and the Nm1 - 1000 XY, £607.95. This may change over time, as more Nm1s are sold, or additional ways to reduce manufacturing costs are implemented. The price of the Nm1 - 400 has gone down slightly since its release earlier this year. The mechanical stage can be purchased with the microscope as, for example, the Nm1 - 1000 XY in Fig 1 and Fig. 2b, or it can be purchased separately as the "XY Slide Indexer". When this article was published, the Indexer was listed at £79.95. In keeping with modern practice, most Newton microscopes and accessories have prices ending with £.95.

For some EEC buyers, and some others, final prices may include an additional tax on the purchase price, i.e., a VAT (Value Added Tax). For example, for UK buyers this tax is currently 20%, a rather high addition to the Newton Microscope prices quoted above. For other buyers outside England there may be other additional charges, e.g., customs duty.


Figure 2. (a) Nm1 - 1000 with stage clips, and (b) the Nm1 - 1000 XY. Figure (a) Courtesy, and with permission, of Rick Dickinson

The mechanical stage, if obtained separately, comes in a plastic case. It is essentially identical in size to that provided to house the Meade Readiview, Fig. 3, and appears to be made of the same material.


Figure 3. Nm1 mechanical stage ("XY Slide Indexer") case

Adapters to connect various cameras to the Nm1s can also be purchased. These include adapters for M42 mounts, £39.95, the Apple iPhone 4 and 5, £17.95, and Android phones, £17.95. Fig. 4 shows two Newton Nm1 camera adapters. Fig. 5 shows one of these adapters connecting the Nm1 and an Olympus DSLR. In addition to the camera adapters, other accessories, sold by the microscopes developers, include a Cullman Nanomax 2000 tripod £34.95, and a Pelican Case £149.

According to the Millennium-Microscope and Newton Microscopes sites, Newton Microscopes were initially developed to diagnose tropical diseases, e.g., malaria, tuberculosis, and helminthic diseases, i.e., diseases relating to parasitic worms, in third world countries, where relatively inexpensive microscopes were felt to be needed.

Owing to "real world" constraints the price of Millennium Health Microscopes (MHMs), [after early evaluation trials the name was changed to Newton Microscopes] were released at considerably higher prices than originally envisioned. To quote from a 2007 paper by Keith Dunning and J. Russell Stothard (Dunning, 2007), "*The MHM could be available within the next two years at no more than 75 USD*." At today's exchange rate, an Nm1 - 400 costs approximately USD $652.63, many times higher than the originally estimated price.

Considering that the Nm1 - 400 is now the only Nm1 version available for purchase without a mechanical stage, its price compared to other Nm1s, is relatively low. Nm1 - 400 users can purchase the optional XY Slide Indexer to be installed in the 400's slide clip stage openings. This makes the price of an Nm1 - 400 XY about £479.90, about £100 less than the cost of an Nm1 - 600 XY.


Figure 4. Two Newton Microscope (Nm1) camera adapters


Figure 5. Olympus DSLR mounted to Newton Microscope

Table 1, reproduced in part, from Part 1 of this paper, provides more details about the Nm1s.

***Newton Microscopes***

| ***Name*** | ***Launch Date*** | ***Sales Date*** | ***~ Number Sold*** | ***Manufacturing Loc.*** | ***Launch Price*** |
|---|---|---|---|---|---|
| Nm1 - 400 | 2013 | 2013 | n/a | China | £412.50 |
| Nm1 - 400 XY | 2013 | 2013 | n/a | China | £492.46 |
| Nm1 - 600 | 2013 | 2013 | n/a | China | £497 |
| Nm1 - 600 XY | 2013 | 2013 | n/a | China | £579.96 |
| Nm1 - 1000 XY | 2011 | 2013 | n/a | China | £607.46 |
| Newton Fluorescence | unk | unk | n/a | China | est. £7-800 |

Table 1. Newton Microscopes

Overly optimistic forecasts for devices to be used in third world countries are, apparently, not uncommon. MIT's Dr. Negroponte of the "One Laptop Per Child" project, established to develop $100 laptops for developing countries, has had similar issues. That project's goals have, to date, proven elusive, as has the USD $75 MHM. Low prices may often be based upon overly optimistic assumptions. These include, (1) forecasts that third-world governments, or other organizations, will buy a very significant number of units, thus allowing for possible cost savings through large-scale production, (2) prices for standard components used in these products will drop significantly, and/or (3) a failure to consider the other devices available to accomplish similar goals, etc.

For example, Newton Microscopes prices are comparable to many traditional binocular benchtop instruments, and these have expanded capabilities and options. Today, weight is often not the factor it once was before the advent of reasonable roads and modern vehicles.

In spite of their higher than originally forecast prices, the Newton Microscopes and indeed all the Dickinson/Dunning folded-optics microscopes are unique. They are modern implementations of Dr. McArthur's folded-optics designs to three-dimensions. Newton Microscopes designed for third world applications deserve praise, in spite of being more costly than their original price goals, as it is hard to know what the prices for these instruments would have been had they had not originally targeted very low price points.

## *Design*

The design goals for the Newton Microscopes were admirable. To quote from the "Introduction" section of their URL (newtonmicroscopes.com, 2013),

> *In contrast with infectious diseases in First World countries from viral and bacterial agents, diseases in the tropics largely result from a very different group of agents: the protists (single celled animals) and helminths (worms). ... entrenching many populations in grinding poverty... the greatest culprit is malaria which is present in 140 countries placing some 3.2 billion people at risk, while for helminths 650 million people are at risk of schistosomiasis.*

The Nm1s were designed to help identify these infectious agents, and thus reduce their impact. However, the Newton Microscope site also notes that while this was the original objective, these microscopes are also suited for use in a variety of other areas including general microscopy.

Figure 6. Newton Microscope optical path. Courtesy, and with permission, of Rick Dickinson

## *Folded-Optics*

All the Newton Microscopes use a unique, compact folded-optics 3D, design as can be seen in Fig. 6. Their size can be compared to other folded-optics microscopes, many available for sale on the used market, e.g., the McArthur, Vickers McArthur, the OU McArthur, the Nikon H, the TWX-1, and the Swift FM-31. In addition, new versions of FM-31 clones are now available for sale, (Kreindler, 2011-1).

The relative size of the Nm1 – 1000 XY microscope compared to some other folded-optics models can be seen in Fig. 7. Note, all Nm1s with the mechanical stage are the same size, as are all Mn1s without this stage.

A variety of manufacturers made metal McArthur microscopes. The two examples included here are representative, and typical of this style. Other Dickinson/Dunning folded-optics microscopes were discussed in Part 1 of this paper. However, these models were not designed, as the Nm1 series was, or the other folded-optics microscopes shown (the OU McArthur being the exception) for serious professional use.


**Figure 7.** ***Newton Microscope and other folded-optics instruments*****. First Row: Nm1 - 1000 XY; Second Row: McArthur, Vickers McArthur, OU McArthur; Third Row: Swift FM-31, New FM-31 Clone, TWX-1, Nikon H**

The comparison Table 2, provides more details for the instruments shown in Fig. 7.

***Comparison of Some Folded-Optics Microscopes*** [1]

| *Name* | *Approximate Size (mms)* [2] | *Approximate Weight (lbs,ozs)/grams* | *Comments* |
|---|---|---|---|
| **Newton Nm1 – 1000 XY** | 158 x 163 x 66mm | 1lb, 6.2oz/629.4g | w mechanical stage |
| **McArthur** | 101 x 50 x 88mm | 1lb, 5.0oz/595.3g | w/o mechanical stage |
| **Vickers McArthur** | 100 x 50 x 65mm | 1lb, 2.0oz/510.3g | w/o mechanical stage |
| **OU McArthur** | 129 x 25 x 75mm | ----, 6.8oz/192.8g | w/o mechanical stage |
| **Nikon H** | 150 x 65 x 109mm | 1lb, 9.2oz/714.4g | w/o mechanical stage |
| **TWX-1** | 131 x 40 x 115mm | 1lb, 9.0oz/708.7g | w/o mechanical stage |
| **Swift FM-31** | 147 x 115 x 108mm | 2lb, 0.2oz/912.9g | w mechanical stage |
| **FM-31 Clone** | 139 x 45 x 100mm | 1lb, 12oz/793.8g | w/o mechanical stage |

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*(1) All folded-optics microscopes were measured without their carry cases.*
*(2) Length (front to back), width, height*

Table 2. Comparison of some folded-optics microscopes

This Table allows us to easily compare the Nm1 - 1000 XY's size and weight to the other folded-optics instruments presented. It length and width are larger, but it is smaller than almost all others in height, even with its mechanical stage mounted. Its mechanical stage is heavy, but four instruments in the table are heavier, including the Swift FM-31, also with a mechanical stage. The Swift FM-31 is almost 70% heavier than the Nm1 - 1000 XY, and for field portable microscopes weight can be an important factor.

## *Unpacking and Use*

My microscope was sent directly from the manufacturer. It arrived in a securely taped corrugated cardboard box approximately 245mm x 100mm x 275mm. The box contained a foam lined plastic case with the Nm1 - 1000 XY. Inside that case was a small plastic case containing four slides: Tilia X.S. of 3-year stem, Pollen Types W.M., Dicotyledon T.S, Sunflower, Zea mays, com L.S. of kernel [one of the world's top cereal crops]. The travel case also contained two Silica Gel packets, a fine focus adapter, a approximately 99mm-square five-fold booklet, a short USB cable, and two stage clips, see Fig. 1. An adapter to connect the microscope to a camera was also shipped in the box, but was packed outside the plastic case.

Fig. 8 shows the foam lined plastic case closed on top of its shipping box, with microscope and manual. The included accessories are in front. The fine focus adapter, an approximately 55mm diameter plastic component with a circular cutout that goes over the focus wheel, is not visible in the photo. It is shown dismounted and mounted in Fig. 9.

Out of the box, the microscope is almost ready to use. All that is required is that the fine focus adapter, if it is to be used, is mounted over the focusing knob. Reading the manual is helpful, but is not necessary to use the microscope, as most functions are easy to understand without instruction.


Figure 8. The Newton Microscope, case, and accessories outside of their shipping box. Slide on microscope is not included.

Figure 9. Newton Microscope's fine focus adapter dismounted and mounted

## *Illumination*

A slide is mounted on the stage, Fig. 8 and the illuminator is turned on via the button shown in Fig. 10. The power to the internal illuminator is provided by 3 AAA batteries located, and accessible, in a compartment underneath the microscope, Fig. 11. Illumination intensity is adjusted by a knurled knob, accessible from the back underside of the microscope; it is shown in Fig. 12. The intensity control is graphically coded to show the direction of increased and decreased brightness.


Figure 10. Newton Microscope illumination toggle


Figure 11. Nm1 battery compartment with its three AAA batteries, underneath the microscope


Figure 12. Knurled illumination adjustment knob

The built-in illumination arm (light arm) can be swung away, so that a slide can be lit by external illumination, Fig. 13. I found this most helpful, as the built-in white LED illumination was too bright for me at 10x magnification, even at its lowest brightness setting.

Figure 13. The light arm is lowered for built in illumination, and raised for external illumination

## *Eyepiece and objectives*

The Nm1 -400, Nm1 - 600, and Nm 1- 1000 are all supplied with RMS 10x wide-field eyepieces. Newtons can have up to three objectives. The Nm1 - 400 comes with two, 10x and 40x. The Nm1 - 600 with three, 10x, 40x, and 60x, and the Nm1 - 1000 uses a 100x oil immersion objective in place of the 60x found in the Nm1 - 600. Thus, magnifications available range from 100x to 1,000x. On the Nm1 - 400 a blank plug is used in place of the third objective. Thus, all Newton Microscopes appear to be of the same design, except for the choice of objectives, and optional mechanical stage.

The field number (FN) of the Nm1s 10x eyepieces is marked as 18. As noted above, the eyepiece is identified as 'WF'. This field number is lower than that found on most benchtop instruments, which often have FNs of 20 and greater. The Nm1 eyepiece has built-in compensation (identified by some makers as 'K', 'C', or 'comp'). Therefore, it is not clear if it could be replaced by another 'Compensation Eyepiece' from a different maker without introducing unexpected chromatic aberrations. Regardless, the Nm1's eyepieces are appropriate for their intended screening purposes.

Although not recommended as it might introduce dust into the microscope's optical system, the NM1 eyepiece can be removed, and reversed, to use as a hand magnifier.

At its greatest, the human eye has an approximately 7mm opening. However, this is generally only true for those below thirty, and in very dark environments. In bright light, the eye's iris constricts and the pupil's opening is reduced, in dim light the opposite happens. Age also affects the size of the eye's opening. As we get older this opening contracts at the rate of about 1mm/two decades, after our first three decades.

The distance above the eyepiece where we can hold our eyes and see the full image field is referred to as eye relief.

On the Newton microscope site, the Nm1 is shown used outside in bright African sunlight. This means that the image from the microscope may be greater than the opening of the eye in these environments, i.e., the full optical capability of the microscope may not be applicable under those conditions. Of course, this would be true for any microscope used in the same circumstances, but less so for a microscope used inside on a benchtop, rather than outside in bright sunlight.

The Nm1 eyepiece was designed to be used without eyeglasses, as its eye relief is rekatively shallow. I have more expensive "High Eye-point" eyepieces on almost all my benchtop instruments, but "High Eye-point" eyepieces are not currently available from/for Newton Microscopes. Users with astigmatism, over 50% of the population and over 80% of eyeglass users, would likely benefit from being able to keep their eyeglasses on when using an Nm1, so what they saw would not be, unnecessarily, distorted.

The objectives can be seen from the top of the microscope. Fig. 14 shows a view of the three objectives used with an Nm1 - 1000 XY. The objectives, although they appear accessible, are not user exchangeable (see below). Thus, e.g., if one desired a Newton microscope with 40x, 60x, and 100x, this would need to be specially configured by the manufacturer.

The turret and surround are black, which might result in heat issues in sunny climates.

The small objectives are marked on their top surface, and their positions are marked on the turret. They use standard color codes (these codes essentially use the spectrum starting at black for the lowest magnification and ending with white as the highest, using cobalt blue, rather than violet, to identify 60 and 63x).

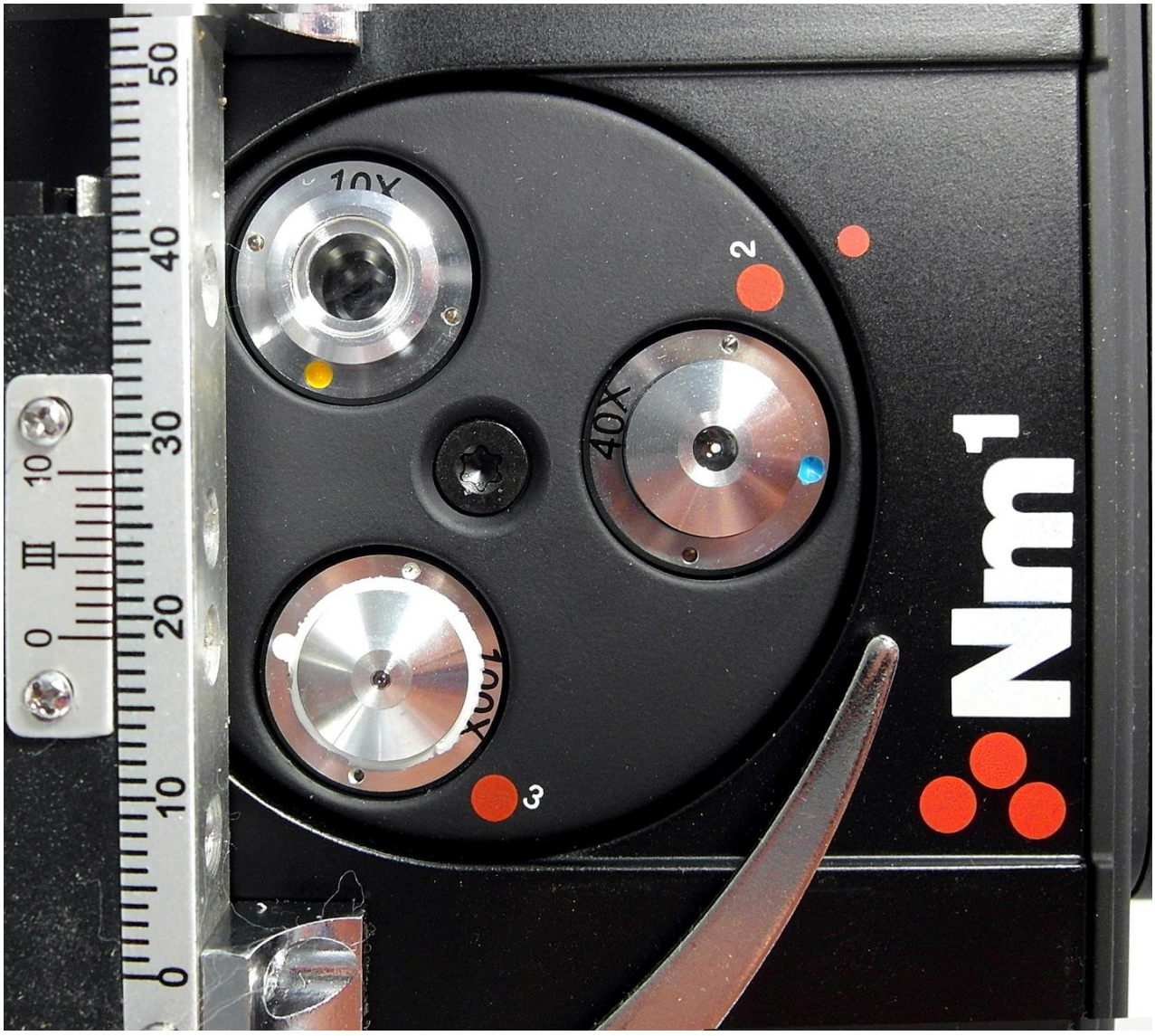


Figure 14. Nm1 -1000 objectives seen from the top of the microscope

The color codes seen in Fig. 14 are 10x yellow, 40x light blue, and 100x white. The 60x objective is coded cobalt (i.e., a dark) blue. The immersion lens does not have a second color code to indicate its immersion media. The position locations on the Nm1 - 1000 are: 1 = 10x, 2 = 40x, and 3 = 100x. On the Nm1 - 600 the third position would contain the 60x rather than a 100x objective. The Newton Microscope URL, http://www.newtonmicroscopes.com/nm1_system.html, lists the lenses numerical apertures as 10x 0.25, 40x 0.65, 60x 0.80, and 100x as 1.25. This URL also provides more details about these microscopes.

A red dot outside the turret indicates the objective currently in use. In Fig. 14, it is the 40x.

The objectives are changed by a continually rotating knob, with click stops, on the bottom of the microscope, Fig. 15. This knob is graphically coded to show the direction of increased / decreased magnification.

Figure 15. Rotating knob under the microscope, used to select objectives

The dimples (pin holes) on the objectives might suggest that they were there to allow users to change the objectives, e.g., to purchase the 60x and 100x and interchange these as needed.

However, to quote an excerpt to me in email from Rick Dickinson,

> *The design intent was precisely that - for the user to be able to add or remove an objective with a tool. This would not be a common thing and would probably be a swap between a 60 and 100, but still useful. However, the small scale of the objectives and the physical reality is such that it is extremely difficult, risky, and beyond the capability of most, and in some cases even rendered impossible due to mechanical effects. For example, I have a specially made tool to retrospectively insert a 60 or 100 into the blank position of a Newton 400, insertion is fine but extraction can be impossible if the objective is tightened down. Extraction of a factory fitted lens is impossible from outside due to the torque required to unlock the thread. Furthermore, the downward pressure required exerts mechanical leverage forces on the focus mechanism, which is undesirable. Then there is the concern for debris falling on the first mirror if the lens extract/insert is done over this location. Future production will remove the two 'pin holes' in the tops of the objectives.*
>
> —(Dickinson, 2013)

Therefore, the objectives are not user changeable, and the current dimples on the objectives will not be present in future releases of the Nm1s.

## *Use*

I found the Newton's unique almost circular shape, rather than the more traditional rectangular design, of a field portable microscope made it more difficult, for me, to hold comfortably. This impression may change over time, as I get to use the microscope more extensively. However, if the slide looked at will allow, the Newton can be turned on its side to look through the eyepiece, and this may prove a steadier way to hold the microscope for some users in the field. The eyepiece for the other field portable, folded-optics, microscopes shown in Fig. 7 all have eyepieces that look down into the microscope. The FM-31 and its clones are also tilted. I found these eyepiece angles, particularly those of the FM-31 and its clones, more comfortable to use. I also find it easier to use a field microscope with a flat bottom, with the eyepiece on top, as this allows me to place the microscope on a convenient surface for more stability when viewing.

The Nm1 series provides two tripod sockets beneath the microscope, front and back, to provide additional options to aid stability. The rear socket seems the appropriate connection if the microscope is to be used without an attached camera. A study tripod, such as the Cullman Nanomax 200 T sold by Newton Microscope with its compact ball head, can provide additional stability for the Newton. This model's designation includes a 'T' to indicate travel, and this tripod weighs only about 700g. However, needing a tripod negatively affects portability. That is, it means extra bulk, and in these situations the Nm1 should be evaluated against more traditional instruments. Fortunately, the Cullman is relatively short even when fully extended, as it does not provide center to leg bracing. The Newton Microscope price for this tripod, £34.95, is less than the typical US price of almost $60, and it can be recommended if you decide to purchase one of the Nm1s.

I found the microscope's tripod sockets somewhat shallow. I had a problem fully inserting the screw from a SLIK tripod with attached head, and could not lock a quick release plate from a Velbon tripod to the microscope. The knob to change objectives is just barely accessible, i.e., with difficulty, if a normal size tripod quick release is used, but presents no accessibility problem for a smaller size one. The shallow sockets should be taken into account if considering a tripod other than the one sold by Newton Microscopes.

For using the microscope when standing, a taller extending tripod with braces from the center column to the legs is probably desirable, and many models are available, although not through Newton Microscopes.

If a camera is attached, the front socket may provide more balance. However, if a camera is used for documentation, since the microscope is monocular, obviously the image viewed is not the same as that seen through the microscope, as it will be modified by the camera's optical system.

## *Optical Performance*

Stability and usability are quite important but, possibly, the most important question for potential users is how the Nm1s optical systems perform compared to other folded-optics microscopes. For this analysis, I used the microscopes shown in Fig. 7 and Table 2 (excluding the OU McArthur). This table summarizes my subjective comparison of these microscopes in three areas: Contrast, Color Fidelity, and Sharpness. I did not attempt to show these factors in side-by-side photos, as I was interested in how the microscope image would appear to a user in the field.

I have summarized my results in Table 3, where I used the following subjective rating scale for the three areas mentioned: Superb, Excellent, Very Good, Good , and Fair. I selected five slides covering a range of areas and objects for this analysis: two from the set supplied with the Newton and three others: (1) Tilia stem, (2) Pollen types, (3) Corpus ventriculi, (4) Jasper, Thin Section, and (5) Diatom mix.

I left the OU McArthur out of this summary, as it was not designed for professional field use. Thus, the resultant ratings, in Table 3, range from Very Good through Superb.

### *Optical Comparison of Some Field Portable, Folded-Optics Microscopes*

| *Name* | *Contrast* | *Color Fidelity* | *Sharpness* |
|---|---|---|---|
| **Newton Nm1 – 1000 XY** | Excellent | Superb | Excellent-Very Good (1) |
| **McArthur** | Very Good | Very Good | Very Good |
| **Vickers McArthur** | Excellent | Superb | Excellent |
| **Nikon H** | Superb | Superb | Superb |
| **TWX-1** | Superb | Superb | Superb |
| **Swift FM-31** | Excellent | Superb | Excellent |
| **FM-31 Clone** | Excellent | Superb | Excellent |

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*(1) It was difficult to get a consistently sharp focus using the Nm1's focus wheel even with the fine focus adapter. This may be this user's issue, or perhaps the focus gearing needs modification.*

Table 3. Optical comparison of folded-optics microscopes

This following, received from Mr. Dickinson, provides further information concerning the Nm1s optical performance,

> *It is theoretically correct to say that the single LED design does not allow the full resolution of the objectives to be attained, as the optimum lighting angle for each objective is not controlled, but in practical terms, it is difficult to see any difference. In fact for the 100x objective, which has an NA of 1.25, it is extremely rare that a conventional microscope is used correctly to gain such performance. The conventional Abbe condensers mostly have an NA of 1.25, but unless the condenser is oiled to the slide as well as the objective being oiled, the maximum resolution cannot be attained. Some of the more expensive aplanatic/achromatic condensers have NAs of 1.4, which means that most users waste even more of the performance (and money).*
>
> – (Dickinson, 2013)

## *Conclusion*

For general microscopy, the Nm1 - 1000 XY is a very attractive instrument that was easy to use. The mechanical stage was a particular pleasure. It was smooth and easy to adjust, and its indexing capability let me return to a location of interest without problem. I also liked the swing-in and swing-out built-in LED lighting capability. It is possibly the easiest to use illuminator I have seen on a field portable microscope. Although at 10x it may provide too much light, for some users, even at its lowest setting. I appreciated the open accessibility to the Nm1's stage, when the built-in LED is swung away. The only other folded-optics models I tested with similar easy accessibility to the stage when a mechanical stage is mounted are the no longer made Swift FM-31, and its current clones. The slide placement locations on later McArthur's, the Nikon H, and the TWX-1 restrict stage access.

The bottom-line question for potential buyers is probably, should I consider an Nm1 microscope. Based on my experience, particularly with its easy to use lighting system, its mechanical stage with graduated indexing, and its convenient stage access, I would say yes.

The only caveat, for me, is the Nm1's focusing mechanism.

I tested the Nm1 - 1000 XY's use in general microscopy, but not against its original design goal of detecting diseases in the third world. Since this was the original motivation for its development, one would hope its performance in this application would be exceptional, particularly as the microscopic determination of malaria in the field is extremely important. To quote the US Government's Centers for Disease Control and Prevention,

> *Microscopic examination remains the "gold standard" for laboratory confirmation of malaria. These tests should be performed immediately when ordered by a health-care provider. They should not be saved for the most qualified staff to perform or batched for convenience. In addition, these tests should not be sent out to reference laboratories with results available only days to weeks later. It is vital that health-care providers receive results from these tests within hours in order to appropriately treat their patients infected with malaria.*

Plasmodium falciparum is somewhat difficult to see in its various stages with a microscope, and is the cause of most deaths from malaria. Thus, it would have been informative to learn how the Nm1s did in detecting this protozoan parasite.

Newton Microscopes paid for testing to evaluate the Nm1's ability in tropical disease diagnosis. These tests were conducted at the Liverpool School of Tropical Medicine. However, their results are company proprietary. Thus, contact information for the Nm1 testers was not available. Therefore, I could not obtain answers from the testers to questions that I, and perhaps some readers here, would have liked to know.

The Nm1s have excellent built-in illumination and indexing mechanical stage. However, if these features are not important for you, I would recommend an FM-31 clone. These can be found at less than 1/3 the price of an Nm1 – 400, and the Swift FM-31 was used extensively in the field with excellent results. Unfortunately, the original Swift Company went bankrupt, and the new Swift Company no longer makes the FM-31. However, FM-31 clones are available new. As the cover of the clone we examined was approximately 90% iron (Kreindler, 2011-1), if this model is used, care must be exercised in wet and damp environments. Artificial light options are available as add-ons for the FM-31 and its clones, although these are not as easy to use as the illumination available on the Nm1s. FM-31 clones have a more traditional rectangular body, and eyepieces that are looked through at a downward angle. The rectangular body and eyepiece configuration means that they are relatively easy to rest on any convenient surface. See our earlier article in Micscape (Kreindler 2011-1) for a more detailed discussion of this microscope.

Optically the two best folded-optics microscopes I tested, in my subjective judgment, were the Nikon H and TWX-1. Of these, the ability to use slides positioned with the cover slip facing upward made the TWX-1 my favorite. Both the Nikon H and TWX-1 produced superb images on all measures considered. In fact, they rivaled some monocular microscopes I have that were designed for benchtop use. However, both, as well as all the others instruments compared in Table 3 are monocular rather than binocular. This, for me, reduces their functionality significantly compared to binocular instruments, as I find seeing with both eyes allows me to detect features that might otherwise be difficult to locate.

I still find the Swift FM-31 a pleasure to use, and although it does not quite produce, for me, the quality of the images from the Nikon H and TWX-1, I still use it in the field as I find its mechanical stage, and tilted eyepiece, a pleasure to use. It uses mirrors, not prisms, and in spite of its aluminum alloy composition, as Table 2 shows, it is relatively heavy, especially with its mechanical stage attached.

The only microscopes in the Table available new today are the FM-31 clone and the Nm1 - 1000 XY. The clone tested did surprisingly well, but did not have an XY indexing stage. For new field portable microscopes, both the Nm1s and the FM-31 clones can be recommended.

If one can find used versions of the highly rated folded-optics instruments mentioned above (Nikon H, or TWX-1) in good working order, these should be considered as viable options, as should the original Swift FM-31 for general microscopy field work.

It is nice to, once again, have so many new professional-grade models of folded-optics, field portable microscopes available.

## *Afterword*

I would have liked to compare the Nm1 - 1000 XY with the soon to be available and likely latest field portable instrument, the Goren microscope (Goren, 2013). This non-folded-optics microscope was named after its designer, Dr. Yuval Goren of Tel Aviv University (currently Visiting Lecturer University College London). It will be produced by MRC International and should be available in April 2014, with a quadruple turret. However, these binocular microscopes should be larger than the Nm1s examined here.

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Walker, Spike (2013) Photomicrographer Spike Walker was kind enough to share his recollections of Dr. McArthur and his work with the Lensman organization, in private correspondence with the author. [Spike Walker is no relation to David Walker, mentioned just above.]

The author welcomes any suggestions for corrections or improvements. He has a continuing interest in folded-optics and field portable microscopes, and stereo and unique historical microscopes.

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