MiSAC matters
MICROBIOLOGY IN SCHOOLS ADVISORY COMMITTEE
50th Anniversary Articles

DIY smartphone microscope

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The practice of using glass spheres as lenses to magnify objects goes back to Anton van Leeuwenhoek who designed a single lens microscope over three hundred years ago. It is possible to design lenses in a microscope to magnify objects today, in the school laboratory, utilizing modern technological developments. Articles on the internet explain how to use glass beads as lenses to magnify objects using smart phones. One site allows you to download information for a 3D printer to print a holder for the glass bead. Setting up the unit and getting good results is, however, a little fiddly and can be time consuming so, for the classroom, the use of a lens from a laser pointer is recommended. There are articles on how to remove the lens from cheap laser pointers, but the best way is to buy the lens directly from a supplier. The lenses can be obtained easily and cheaply on the internet from a range of suppliers in China.

Many pupils have smart mobile phones with a camera and, with a plastic laser lens and a little care and effort, the phone can be modified to work as a microscope. If the lens is attached correctly to the phone, it will allow images to be magnified approximately 75 times. Many phones can also enlarge the image by zooming in and producing a greater magnified field of vision. Mobile smart phone microscopes can be used to examine a range of prepared microscope slides, as well as wet mounts of fungi, yeasts and algae.

To obtain clear images it is advisable to build a holding frame for both the phone and the slide. The one described here holds the phone in a set position and allows the slide to be moved up and down to ensure the image can be focused by the phone (**Figure 1**). A battery-powered LED light unit allows illumination of the slide, producing a brighter, clearer image on the phone. The construction requires a small amount of DIY with Lego™ bricks. Four bricks need to be modified: two plates and two bricks (blue and red in **Figure 1A** respectively). A 5 mm diameter hole is drilled into the bricks, to allow the plastic bolts to fit through the bricks (**Figure 1B**). The two plastic bolts and plastic wing nuts hold the stage in place and allow it to be moved freely up and down.

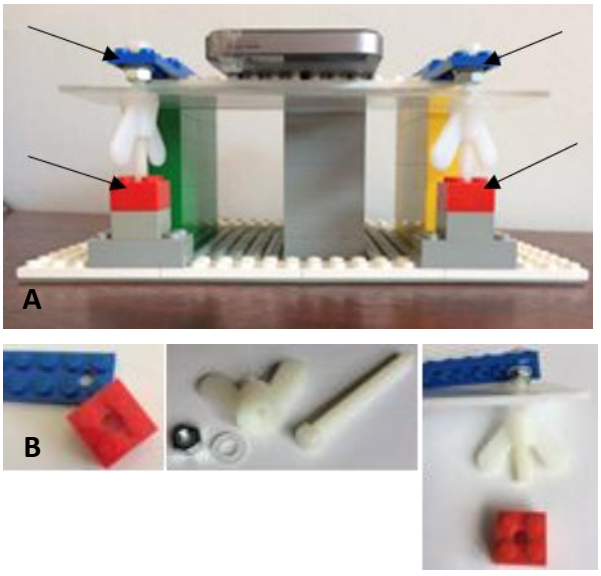

Figure 1 (**A**) Both the red cube bricks and the blue plates have been drilled to allow the insertion of the white plastic bolts with wing nuts (arrowed). (**B**) Assembly of the slide stage: A 5 mm hole drilled in a 2 x 2 brick and a 2 x 8 plate. Plastic bolt and wing nut with a washer and metal nut. The metal nut and washer hold the plastic bolt tight to the blue plate which allows the wing nut to raise and lower the stage. The 5 mm hole is the same size as the inside dimensions of the plastic tube found on the undersides of the brick. The drill can be easily guided down the tube to cut the hole in the brick.

The lens is attached to the phone with a small piece of masking tape or sellotape. A paper punch is used to cut a circular hole in the middle of the small piece of tape. The lens suggested for use here is just fractionally larger than the hole and can, with care, be placed on the tape so that the lens is attached all the way round the edge of the hole (**Figure 2A**). The lens can then be fixed to the phone with the tape, so that it fits exactly over the phone's camera aperture (**Figure 2B**).

Figure 2 (**A**) Tape attached to the rim of the lens. The hole cut just fits over the lens rim. (**B**) Lens positioned on the phone and held in place with tape.

A little care is needed to ensure correct alignment of the lens over the camera aperture. It is often easier to place the phone upside down with the camera aperture facing upwards. The lens is attached to the tape and then carefully lowered onto the phone and the tape used to fix it in place. The lens used to make the microscope above, was a high quality laser pointer lens with clean surfaces (a 7 mm x 3.3 mm lens with a focal length of 6.8 mm constructed of PMMA-Perspex).

On close examination of the lens from the side, you will see that one side has a thin transparent rim whilst the other has none (**Figure 3**). The rim side of the lens should face away from the camera lens. The other side with no rim should be against the phone. The laser lens could be placed either way round, but it will work better - the field of view will be larger - if you follow the suggested orientation. For the connoisseur, two lenses can be placed one on top of the other which will produce increased magnification.

Figure 3. Lens showing the thin transparent rim.

The stage on which the microscope slide rests is made from milky Perspex. Clear Perspex can be used, but a sheet of thin white paper cut to size will need to be used to disperse the light. The Perspex used to construct the microscope stage, as shown, was 2 mm thick and measured 150 mm x 40 mm (**Figure 4**). Two holes were drilled in the Perspex stage to line up with the plastic bolts and wing nuts. The holes were drilled with a 6 mm drill bit, to ensure the Perspex stage rests on the wing nuts and can move up and down freely when the wing nuts are rotated. Free movement of the stage is essential to ensure specimens can be focused by the lens which is fixed to the phone.

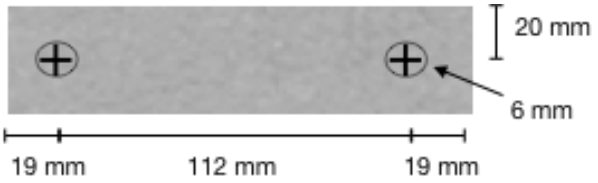

Figure 4. Perspex stage dimensions.

There are two methods to illuminate the specimen. One way is to purchase from internet sites a modified transparent Lego™ brick which contains batteries and a LED bulb

(**Figure 5**). Alternatively, you can obtain a DIY electronic kit from Electron Laboratory Products. It has produced a special Lego™ LED Printed Circuit Board kit (**Figure 5**). The PCB fits directly on the brick, but needs a little soldering to build. Some experience of soldering is required; a novice might have issues with attaching the minuscule current-limiting resistor.

The advantage of this circuit board is that it has two holes which fit on the lugs of the Lego™ plate and thus holds the LED in place below the Perspex stage. The unit is powered by a 9 volt battery which means the light can be used for a long time.

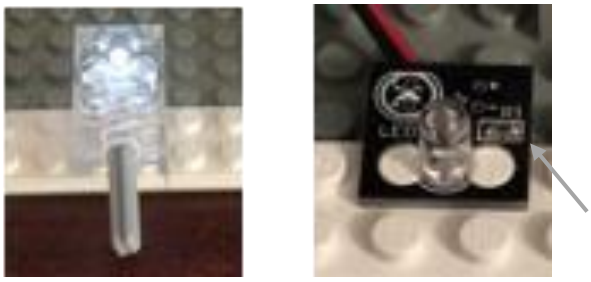

Figure 5. Left: a clear Lego™ brick with LED and battery fitted inside the brick. Right: PCB with LED and minuscule resistor (arrowed) fitted onto the studs of a Lego™ plate.

The phone holder (**Figure 6**) is constructed from Lego™ bricks, which can be obtained from internet web sites that supply bricks or from the Lego™ Brick web site.

List of bricks used per unit:

Base plate: 16 x 16 or 24 x 24 studs

Bricks: 2 bricks 2 x 2 studs
2 bricks 2 x 2 studs (drilled hole)
16 bricks 2 x 4 studs
14 bricks 2 x 10 studs

Plates: 18 plates 2 x 6 studs
8 plates 2 x 8 studs
2 plates 2 x 8 studs (drilled hole)

Figure 6. Phone and holding unit.

Comparative fields of vision on a smartphone

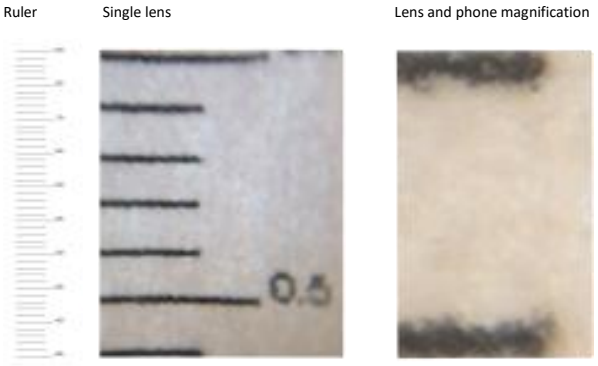

Figure 7 (**A**) The field of view of the smart phone screen was 4.5 cm. (**B**) When a lens is used with the phone only, 0.6 cm of the ruler is now visible. (**C**) If the phone magnification is also used, then only 0.1 cm of the 4.5 cm ruler is visible on the phone screen. This means that there is a x 75 magnification with the single pointer lens and a maximum of x 450 with the lens and phone. Different phones will have different fields of view and phone enlargement, so each will need to be calibrated to work out the magnification.

The following images were taken with a smart phone (iPhone SE) + a single laser lens.

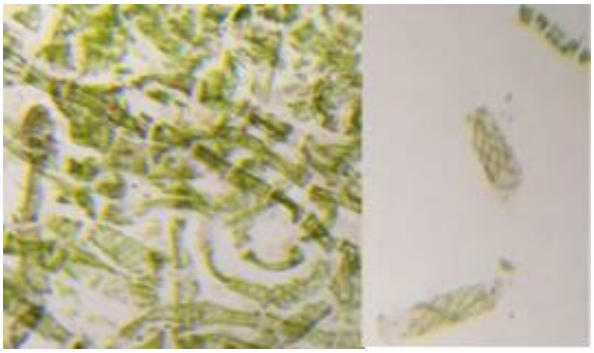

Figure 8. Pond algae using a wet mount (x 450)

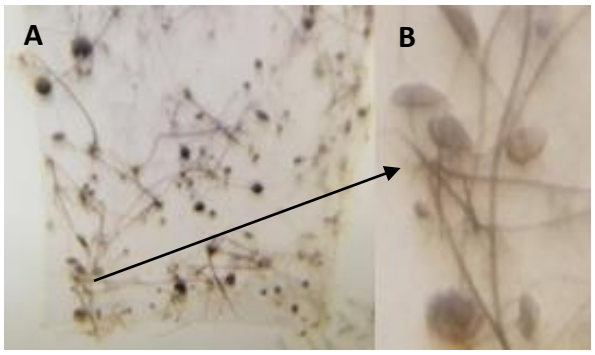

Figure 9 (**A**) *Rhizopus* fungal mycelium and sporangia (x 75). (**B**) Magnified region of wet mount at highest magnification (x 450).

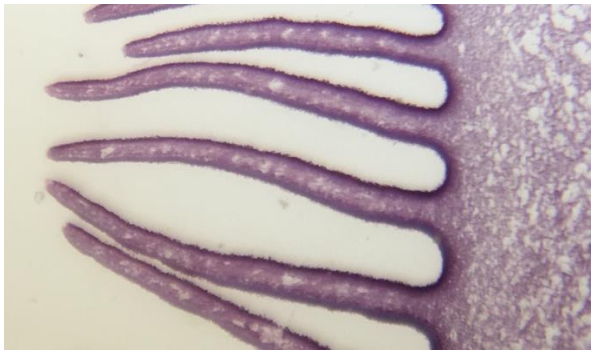
Figure 10. Microscope slide: Pileus T.S. of field mushroom *Agaricus campestris* (x 150)

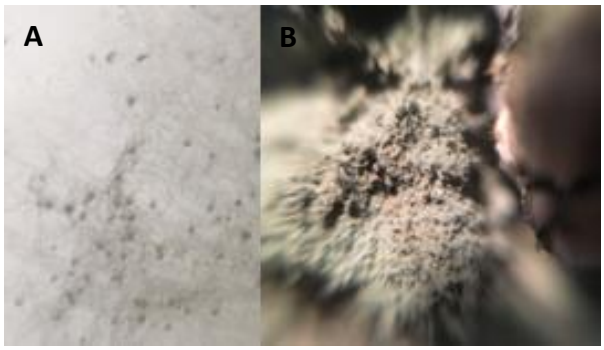

Figure 11 (**A**) Black bread mould fungus; mycelium and spores collected using sticky tape (x 150). (**B**) *Penicillium* growing on a dried grape (x 450).

References

Pacific Northwest National Laboratory. *PNNL Smartphone Microscope* https://availabletechnologies.pnnl.gov/technology.asp?id=393

Pacific Northwest National Laboratory. *3D printer technology and glass beads - a powerful combination* https://www.pnnl.gov/news/release.aspx?id=1071

Instructables. *$10 Smartphone to Digital Microscope Conversion* https://www.instructables.com/id/10-Smartphone-to-digital-microscope-conversion/

Information for construction

Laser lenses obtained from AliExpress https://www.aliexpress.com/item/HJV-7-Wholesale-Retail-Laser-Lens-Laser-pointer-lens-Clean-surface-Size-7X3-3mm-PMMAmaterials/32229025388.html?spm=a2g0s.12269583.0.0.3c45fa3bCOAV4f Seller: *Jarmay store*

Nylon standard wing nuts M5 / 5 mm, Item ID 111926847350 (Pack of 20), ebay seller: *Bolt-world*

Nylon bolts M5 x 50 mm long, Item ID 141774408269. (pack of 10), ebay seller: *Spares immaculate*

Acrylic (Perspex) slide stage: *The Plastic Man* https://www.theplasticman.co.uk/index.php?area=calculator&gclid=EAIaIQobChMIo_7h4tbd3wIVArDtCh1sLg-HEAAYAyAAEgKP3vD_BwE#calc

Lego bricks: https://pickabrick2.brickowl.com

Lego Shop: https://shop.lego.com/en-GB/PAB-Bricks
- White plate 2 x 6 studs (379501)
- Blue plate 2 x 8 studs (303423)
- Grey base plate 16 x 16 studs (6004927)
- Red brick 2 x 2 studs (300321)
- Grey brick 2 x 4 studs (4211085)
- White brick 2 x 10 studs (4617855)

Light PCB, Elektorized Lego LED kit (150244-71) https://www.elektor.com/legoled

2 x LED Lunar lights compatible with Lego blocks white light & battery, Item ID 173192897169, ebay seller: *kidzcrazefu*n

AUTHOR PROFILE

John Schollar was, until 2016, the Director of the National Centre for Biotechnology Education (NCBE). He began his working career as a teacher in a boys' grammar school in South London, from where he moved to teach in a mixed comprehensive school in Berkshire. He was appointed to a project to develop biotechnology training materials for teachers before becoming a co-director at the NCBE; a science education Centre at the University of Reading. He was awarded an honorary doctorate from the University of Gothenburg in 2001. John has run CPD workshops for teachers in microbiology and biology enhancement courses for secondary school pupils across the UK.