



An RMS Approved Microscope for Secondary Schools:

A further development in the RMS's Outreach Programme

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Perhaps the most enduring legacy of the RMS's 150th Anniversary Celebrations in 1989 has been the contribution to the public understanding of science brought about by the Exhibition at the Science Museum in London. What was particularly evident was the enthusiasm and interest shown by children: the excitement of seeing the fine details of things invisible to their naked eyes and opening up a whole new realm of the world about them. Here we saw education at its best – (literally) a 'leading out', a voyage of discovery.



Figure 1: RMS Activity Kit with specimens, microscope and activity sheets.

But – and it was a big but – the RMS then had no educational programme to support and follow on that enthusiasm. The matter was earnestly discussed in Council and the wise decision was made that the RMS's efforts should be directed to the needs of primary school children where the field was 'wide open', where there were no potential constraints in the syllabus and there were no artificial distinctions between 'science' and 'arts' activities at all.

The first task to be addressed was to identify the type of microscope most appropriate for six to eleven year olds. It was quickly realised that a wide range of 'microscopes' and 'magnifiers' were (and are) available on the market – some near-useless or worse-than-useless.

One microscope stood apart – the Motic MS2, soon to be followed by microscopes of similar design

and construction (e.g. the Junior Monoscope) and available from various suppliers. These are of sturdy construction, with rack-and-pinion focusing and do not require the use of glass slides. As with stereomicroscopes and magnifiers, specimens (which need no special preparation), are viewed by reflected light. The fixed magnification of 20x gives a large (~9 mm) field of view and a large (~80 mm) working distance. A magnification in the range 20x ~ 30x is very important: it is sufficient to reveal to children fine detail unresolved by their naked eyes and yet is not so large that the connection between the specimen itself and the fine detail is lost. These mechanical and optical characteristics were summarised as a *List of Design Criteria* for RMS Approved Microscopes for Primary Schools.

These microscopes became the basis of the 'A Microscope for Every School' (AMFES) initiative,

launched in 1995 by the then President of the RMS, Peter Goodhew, during 'SET 95 Week' – the week of Science, Engineering and Technology organised by the British Association for the Advancement of Science (now the British Science Association).

In order to assist primary schools to purchase 'RMS Approved Microscopes', an 'AMFES Fund' was set up, the income for which comes from the RMS's outreach budget and from the sales of ex-laboratory microscopes to amateur microscopists. The Fund contributes £25 (nearly half the cost) of each microscope purchased by a primary school and to date the purchase of several thousand microscopes have been supported in this way.

The progress of the AMFES initiative and the associated British Nuclear Fuels (BNFL) sponsored 'Young Detectives' pack is fully described by John Hutchison in 'Moving Forward: The Royal Microscopical Society 1989-2014'. We should also record the great contribution made by the late Juliet Dyson, co-author of the little booklet 'The Beginner's Microscope', who engaged the interest of teachers

both at the annual meetings of the Association for Science Education and by her visits to schools.

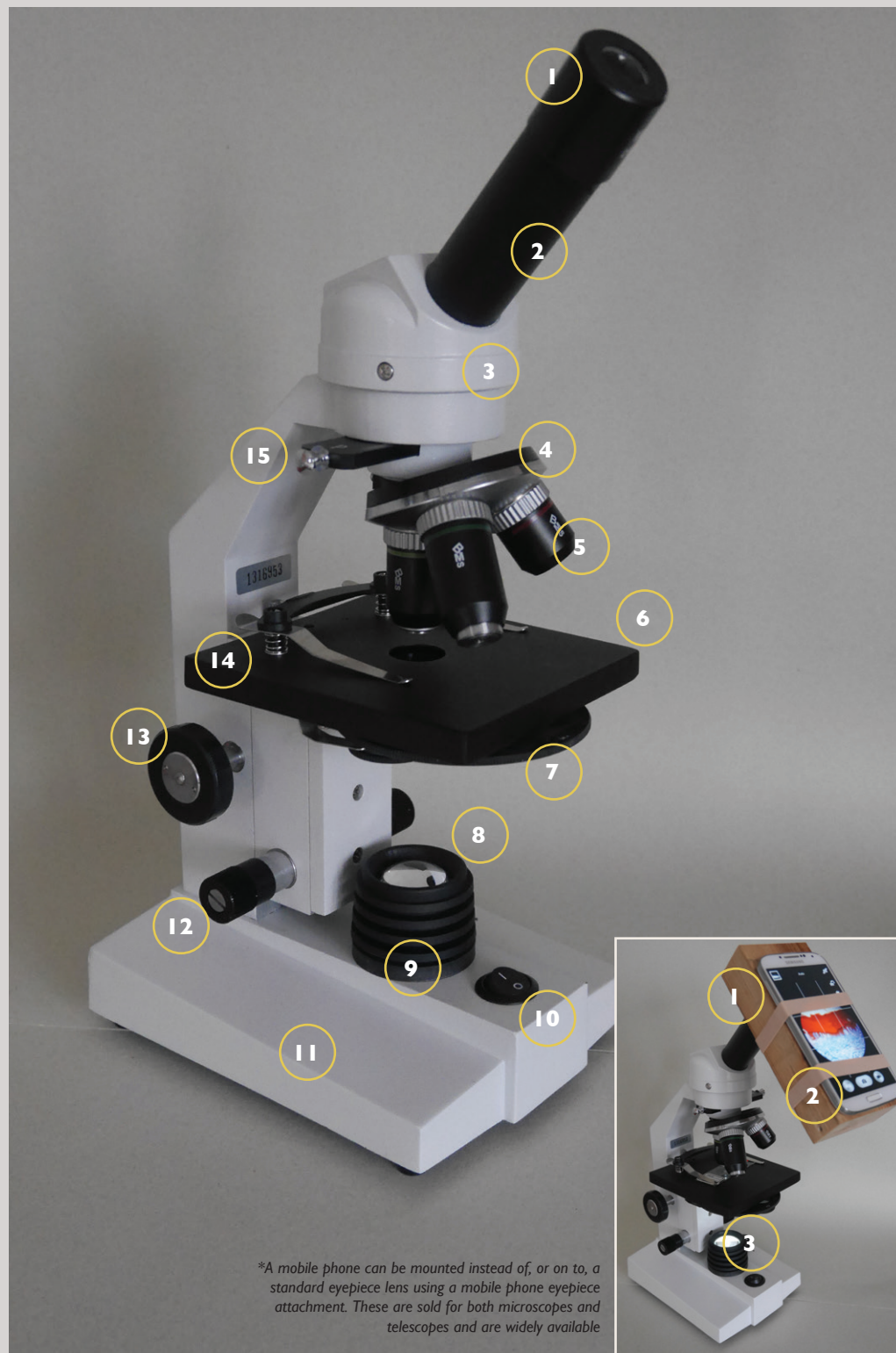
In the last few years, following the establishment of the *Outreach & Education Committee*, a 'quantum leap' has been made in the setting up, organisation and distribution of RMS Microscope Activity Kits (Figures 1 and 2). These include worksheets, sets of specimens (as starters) and a further RMS Approved Microscope – a binocular (useable with both eyes or only one eye) – and which incorporates a built-in LED light source, dispensing with the need for an external lamp.

Hence, in a period of 25 years the RMS's outreach programme for primary schools is fully established.

Now the RMS is in a position to address the microscopical needs of secondary schools and here the task is perhaps more difficult. On the one hand there is a vast range of 'conventional' (generally thought of as 'biological') microscopes on the market and on the other a natural disinclination for teachers to invest in instruments which they and



Figure 2: Children (Irchester Community Primary School) using the kits.



*A mobile phone can be mounted instead of, or on to, a standard eyepiece lens using a mobile phone eyepiece attachment. These are sold for both microscopes and telescopes and are widely available

Figure 3: The RMS1001 microscope (a), with its various components indicated as described in the text, and inset (b) a Samsung Galaxy S4 mobile phone held with rubber bands above the eyepiece on a block of wood. All subsequent pictures were taken with this setup.

Annotations for Figure 3(a)

1. 10x eyepiece with locking screw to eyetube
2. Eyepiece tube
3. Inclined monocular head
4. 3-position nosepiece
5. 4x, 10x and 20x objectives
6. Condenser fixed just below the stage
7. Rotating disc with diaphragms, dark field stop and polarising filter (polariser)
8. Light intensity control knob (on right hand side, hidden from view)
9. LED lamp housing
10. On/off switch
11. Base containing rechargeable batteries and 7.5 volt connection socket at the rear
12. Fine focus knob
13. Coarse focus knob
14. Square stage with slide clips
15. Slider with polarising filter (analyser)

Annotations for Figure 3(b)

1. Block of wood to provide a platform for the mobile phone. The bored hole may be lined with thin card to fit tightly over the eyepiece
2. Mobile phone attached to block with rubber bands. The phone lens should be about 16mm above the top lens of the eyepiece
3. Light intensity control knob (hidden from view)

their pupils may find difficult to use (and easy to misuse) and which are invariably associated only with 'biology'. How many microscopes, replete with oil immersion objectives, mirrors and condensers, gather dust at the back of school cupboards!

Hence, as before, there was a need to specify the characteristics of an 'RMS Approved Microscope' for secondary schools. The criteria, which have been arrived at after much discussion within the RMS and with school teachers who have direct experience of microscopy in the classroom, are set out below



Figure 4: A webcam mounted above microscope eyepiece, held in place by a rubber band and a film container. This provides an alternative to the mobile phone arrangement.

– which, it is hoped, will be of particular value to manufacturers and suppliers of microscopes. Note in particular that they embrace a particular range of (total, linear) magnifications (40x – 200x), three imaging techniques (bright field, dark field, polarised light) and can be used both for viewing 'directly', or, with the use of an attachable digital camera, for display on a screen or laptop. The criteria exclude the range of so-called digital microscopes which have no eyepiece – i.e. no facility for direct viewing.

At present there is only one instrument in the market which fulfils these criteria (the RMS1001 RMS microscope supplied by SciChem) – which is shown with the various components annotated in Figure 3. However, we anticipate that other microscope firms will offer instruments with similar facilities in due course.

The images which follow illustrate the capabilities of the instrument and show the great advantage to be gained in being able to switch between the three imaging modes. All have been taken using a mobile phone, as shown in Figure 3(b), the circular images representing the full field as seen through the eyepiece.

Design Criteria for an RMS Approved Microscope for Secondary Schools

- (1) An inclined monocular or binocular viewing head via a prism (lower or higher cost alternatives) allowing the stage to remain horizontal.
- (2) Removable 10x eyepiece (allowing insertion/addition of a digital camera).
- (3) An illuminating system built into the base of the instrument, incorporating an LED light source powered by rechargeable batteries, and provided with a mains adapter such that the microscope can be used with or without connection to the mains.
- (4) Three objective lenses set in a revolving turret or nosepiece with magnification and numerical aperture (NA) values:
4x/0.1 NA; 10x/0.25 NA; 20x/0.40 NA
This set provides a good range of NA (resolution), total magnification (40 – 200x) and field of view (approximately 4mm – 1mm).
Note: this range includes a 20x/0.45 NA objective rather than the 40x/0.65 NA objective normally fitted. The 100x/1.3 NA oil immersion objective is similarly excluded, though both could be available as optional extras.
- (5) A plain stage with slide-clips, avoiding both the cost of a mechanical stage and the potential damage to the objectives with which it is likely to come into contact on rotation of the nosepiece.
- (6) A condenser lens in a fixed position below the stage, i.e. with no facility for mis-adjustment. The condenser must fill with light the whole field of view of the 5x objective and also provide a sufficiently wide cone of light for the 20x objective.
- (7) A rotating aperture/filter disc fixed to the underside of the stage at a distance such that the diaphragms (see (8) below) lie approximately in the first focal plane of the condenser lens.
- (8) (a) 2 diaphragms of different sizes (to limit the angle of the cone of light from the condenser and to achieve, for each objective, near-optimum conditions for resolution and contrast).
(b) A central 'dark ground' stop which blocks the light which (in bright field) normally passes from the condenser directly into the objective, but which allows the light scattered from the specimen to enter the objective.
(c) A polarising filter (polariser) to be used in conjunction with an analyser (see (9) below).
- (9) Incorporation of a slider below the inclination-prism with an in/out polarising filter (analyser) to be used in conjunction with the polariser (see (8)(c) above)



Figure 5: The head of a mosquito larva in bright field (a) and dark field (b). Notice that the fine hairs projecting from the head, which scatter light only weakly, are clearly visible in dark field against the black background. [Field of view 2mm]

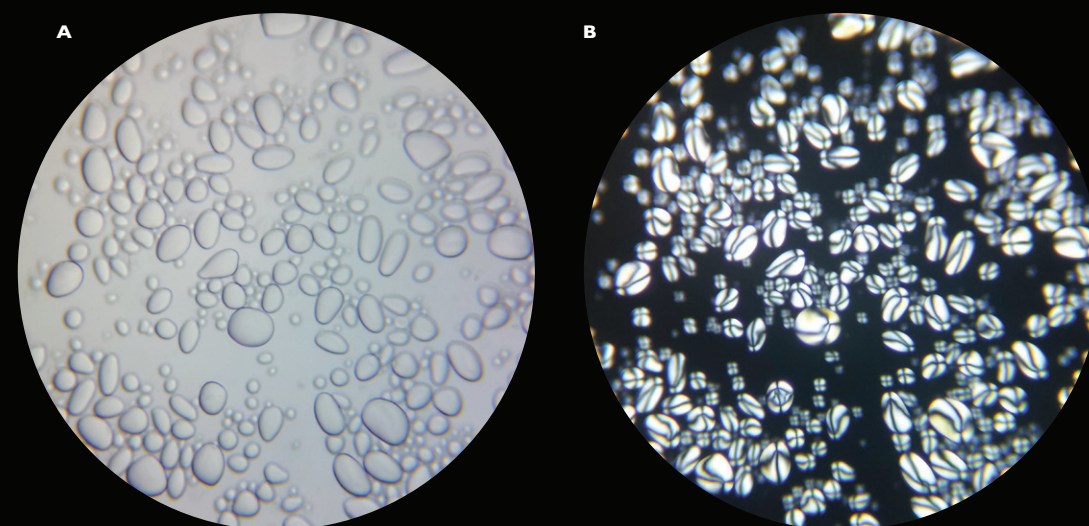


Figure 6: Potato starch grains, (a) in bright field, showing little contrast, and in (b) the polarised-light image ('between crossed polars'), which reveals the optical properties of the arrangement of the starch molecules. [Field of view 1mm]

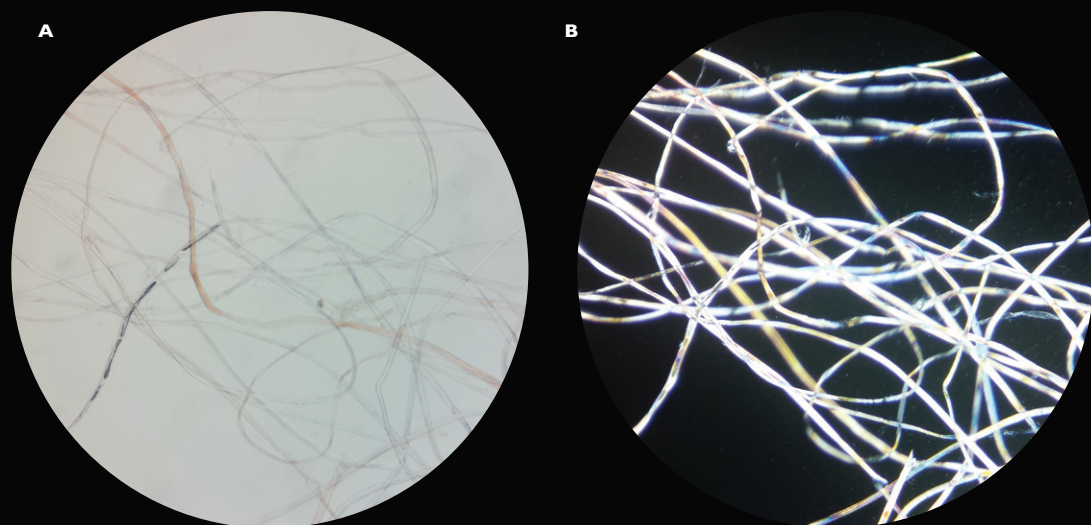


Figure 7: Cotton fibres, again in bright field (a) with low contrast, and in (b) between crossed polars. [Field of view 2mm]

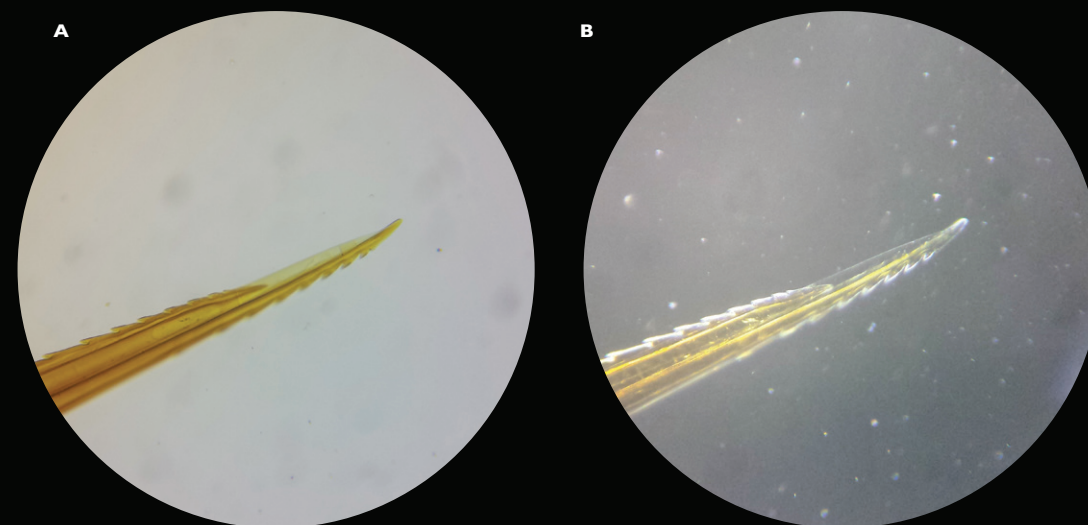


Figure 9: A wasp sting, (a) in bright field, and (b) in dark field. [Field of view 1mm]

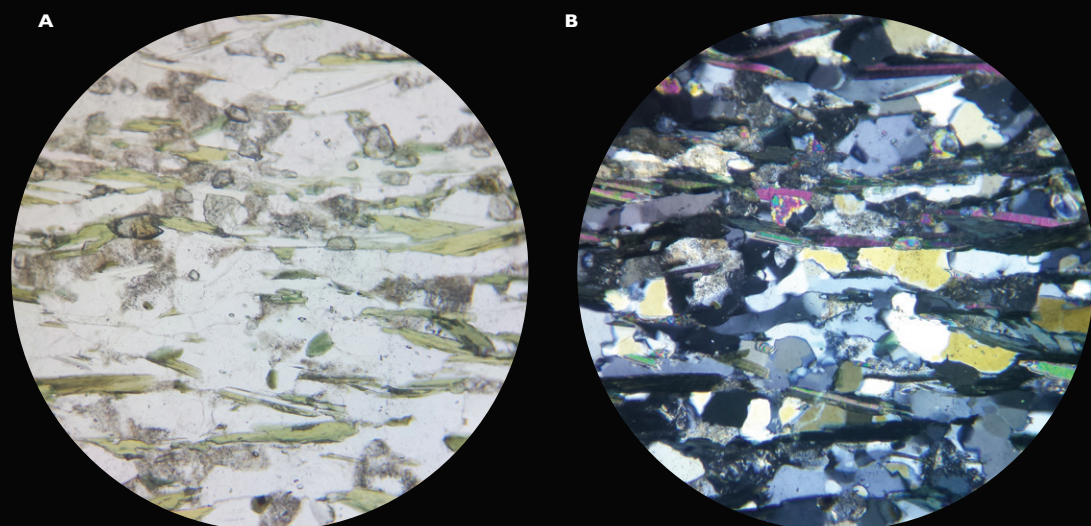


Figure 8: A thin section of rock with grains of quartz and mica, in bright field (a) and between crossed polars (b). [Field of view 2mm]

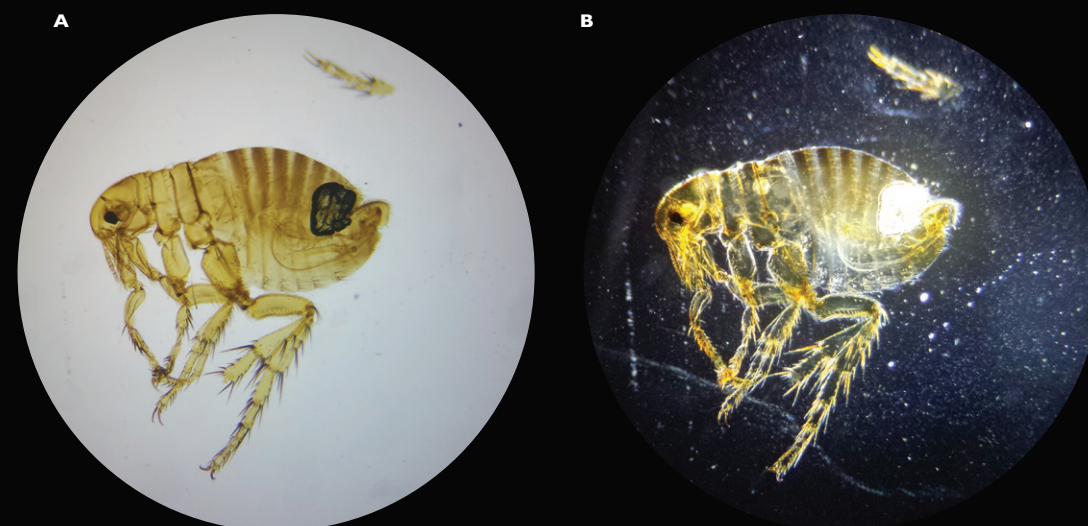


Figure 10: A cat flea, (a) in bright field and (b) in dark field. Note how dark field reveals specks of dust in the background, invisible in bright field. This apparent nuisance can be an advantage in detecting very small particles. [Field of view 5mm]

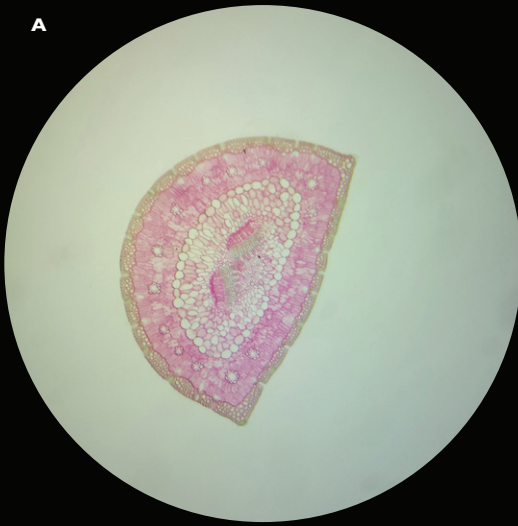


Figure 11: A cross section of a pine needle, (a) in bright field and (b) between crossed polars. [Field of view 5mm]

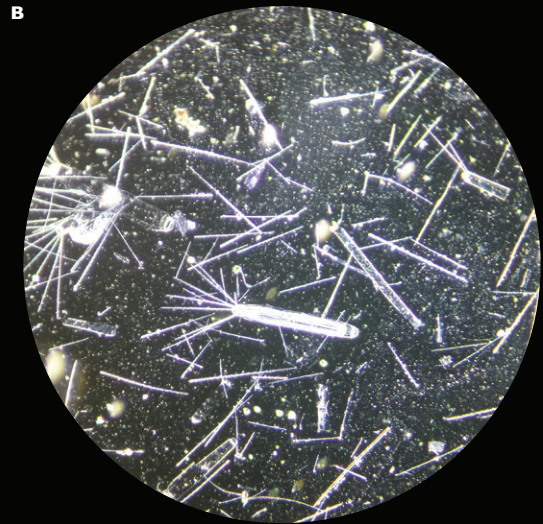
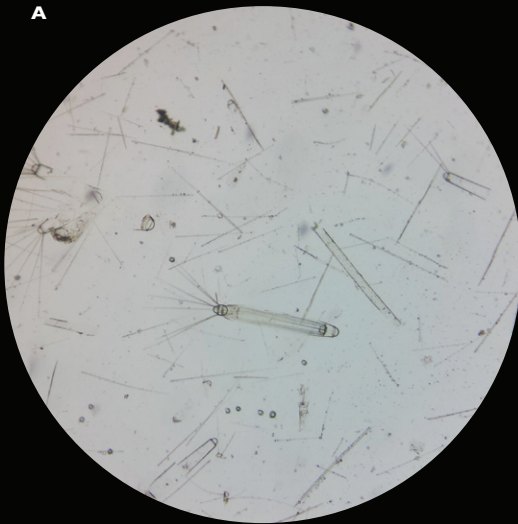


Figure 12: A stew of diatoms, (a) in bright field and (b) in dark field. [Field of view 1mm]