

MIM Tube Lenses and Assemblies

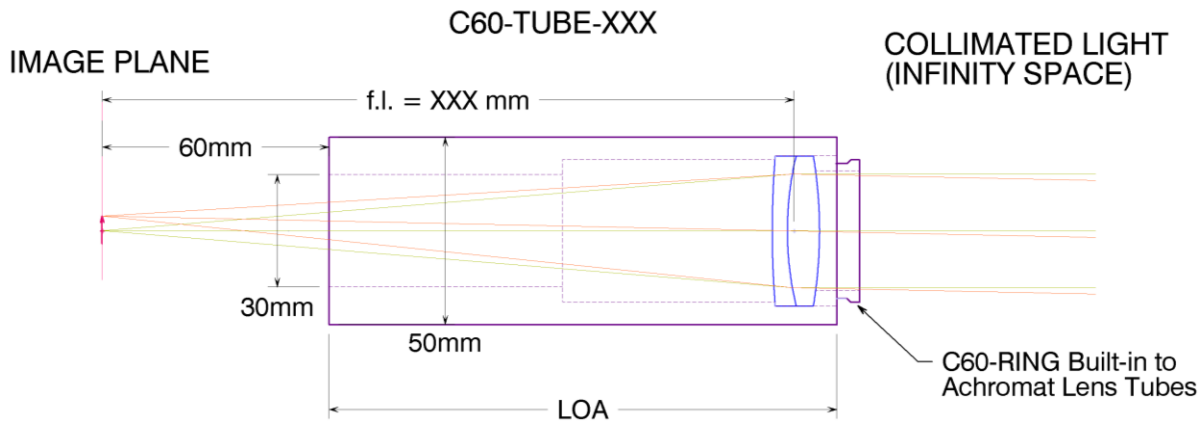


Figure 1: Basic tube lens focuses collimated light into an image.

ASI Modular Microscope components consist of tube lenses along with adapters and accessories that either are primarily used in the collimated light space or adapters that are to be used on the image side. Collimated light adapters use the 38mm diameter C60-RING system to connect components. Focus-side adapters attached to lens tubes with either a 30mm diameter coupling to the I.D. of the C60-TUBE, or with a 50mm coupling on the O.D. of the lens tube.

With infinity microscope systems, the objective can be spaced away from the tube lens without changing the optical magnification. This “infinity space” provides a region where other optical systems can be coupled to the microscope relatively easily. For epi-fluorescent illumination, a filter cube with a dichroic beam splitter can be added to provide the illumination path.



For best imaging performance we recommend the **C60_Tube_B** which uses a Nikon 200mm multi-element tube lens.

Other Tube Lens Assemblies

In addition to the standard **C60-TUBE-B**, there are also several other options for tubes and tube lenses that can be used to obtain different final magnifications. The achromatic lens tubes, **Tube-100**, **Tube-200**, etc., include the male ring end built into the assembly. A coupling **C60-RING** is required for **Tube-B** and **Tube-Z13**.

The distance from the end of the tube to the image plane is 60 mm for all tubes. The tubes have a 50mm O.D. and are terminated with a 30mm I.D. flange. The table below lists the other options and specifications for the various tube lens assemblies.

Part Number	Lens F.L. (mm)	Magnification for Nikon Objectives	Magnification for Olympus Objectives	Lens type	Length of Assembly (mm)
C60-TUBE-B	200	1.00	1.11	Nikon multi-element tube lens	126.2
C60-TUBE-Z13	164.5	NA	NA	Zeiss multi-element tube lens for 130mm objective-tube distance	121.1
C60-TUBE-100	100	0.50	0.56	Achromat	48.7
C60-TUBE-100D	100	0.50	0.56	Dual Achromat	63.9
C60-TUBE-160	160	0.80	0.89	Achromat	112.3
C60-TUBE-180D	180	0.90	1.00	Dual Achromat	?
C60-TUBE-200	200	1.00	1.11	Achromat	152.7
C60-TUBE-300	300	1.50	1.67	Achromat	252.0
C60-TUBE-400	400	2.00	2.22	Achromat	352.0



C60-Tube-100



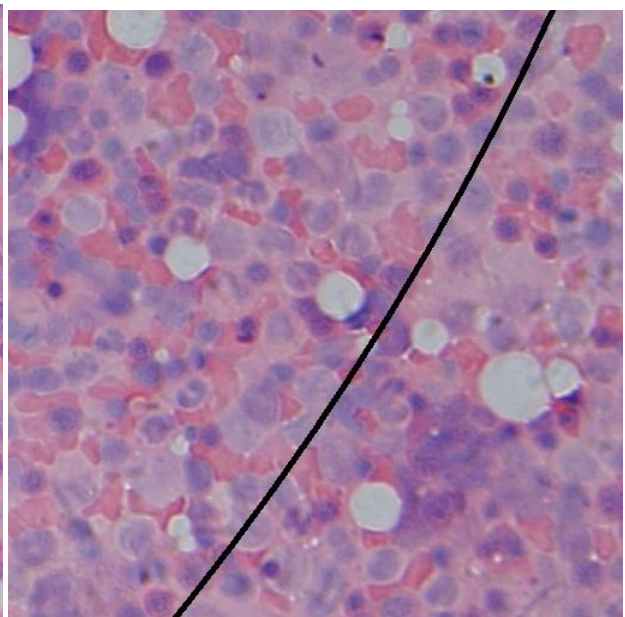
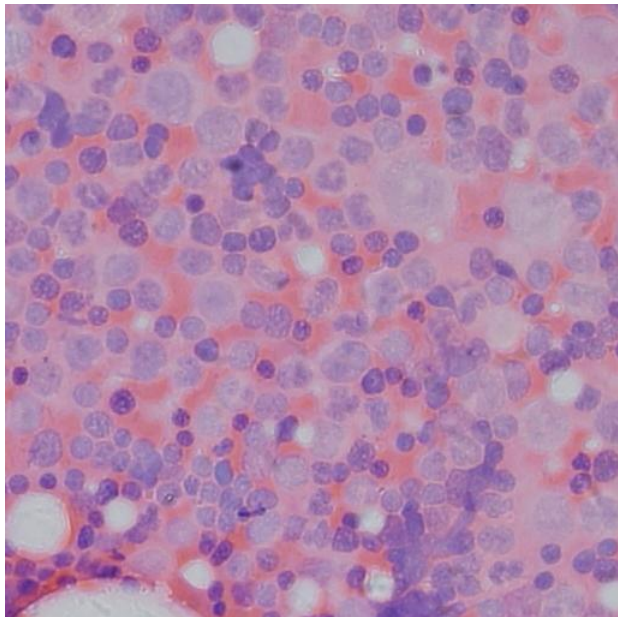
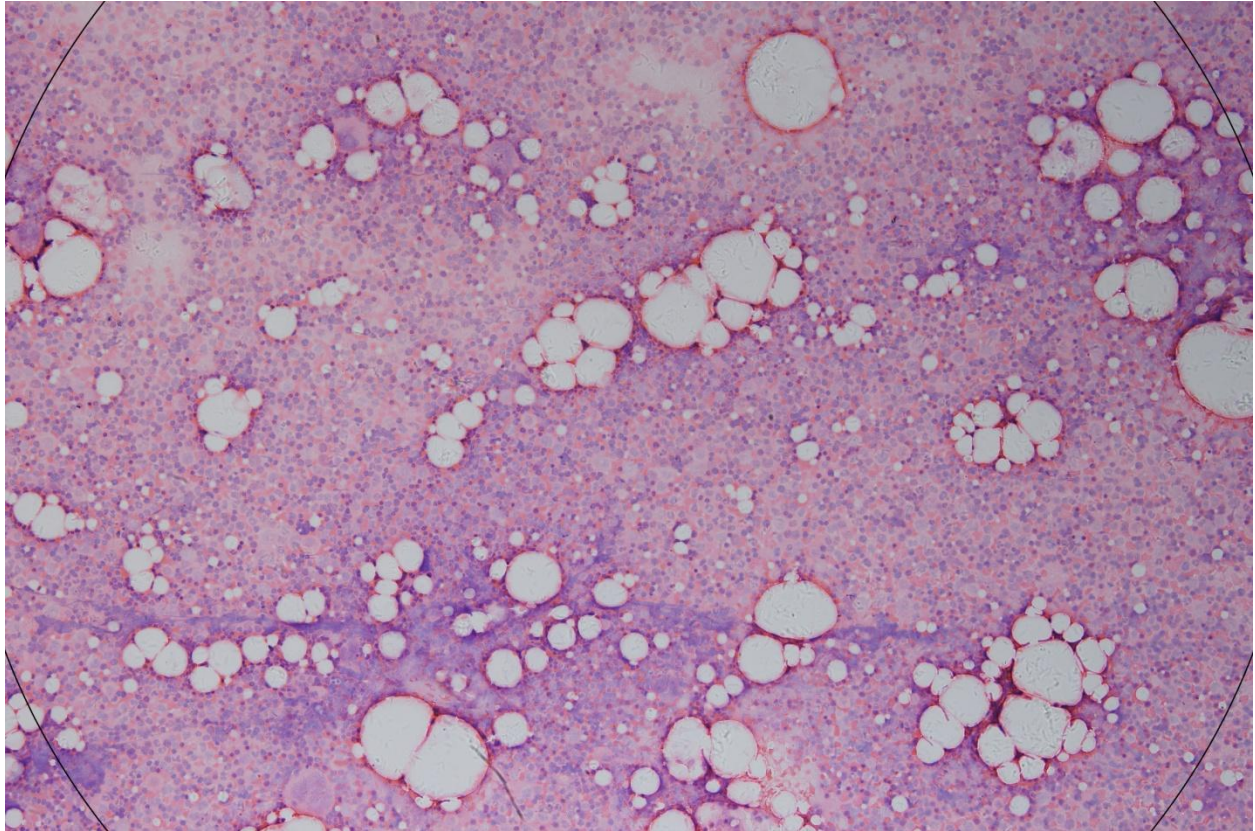
C60-Tube-200

Tube Lens Performance

Imaging performance of the tube lens will depend upon the suitable combination of lens and objective, the field of view in the image, and the focal length of the tube lens. In general, longer focal length lenses will have better performance across the field of view. To illustrate this, we show some sample images taken with a variety of tube-lens and objective lens combinations. All of the images are of a fixed stained bone marrow smear which provides a nice uniform large area color sample with large spatial dynamic range. The images show a reference circle corresponding to a 25mm field number (FN) for the objective. Magnified sections of the image in the center of the field and near the objective design FN are shown as well. Images were taken using a Sony NEX-3 camera with 23.4 mm x 15.6 mm sensor with 5.1 μ pixels. I did my best to focus accurately the center of each image.

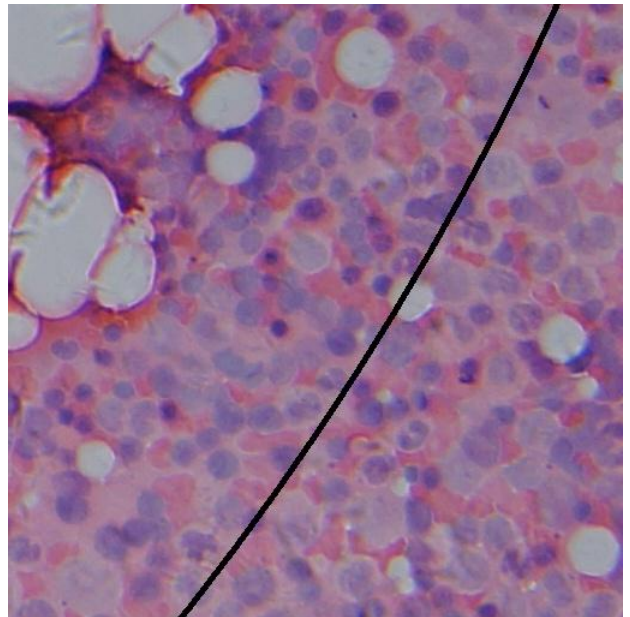
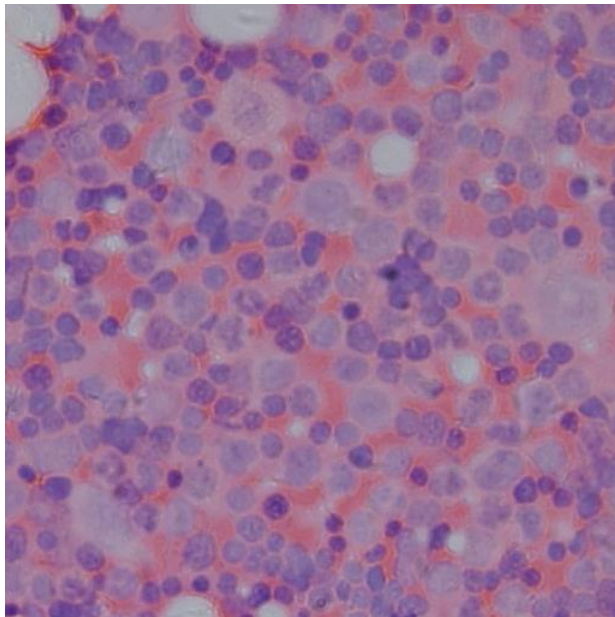
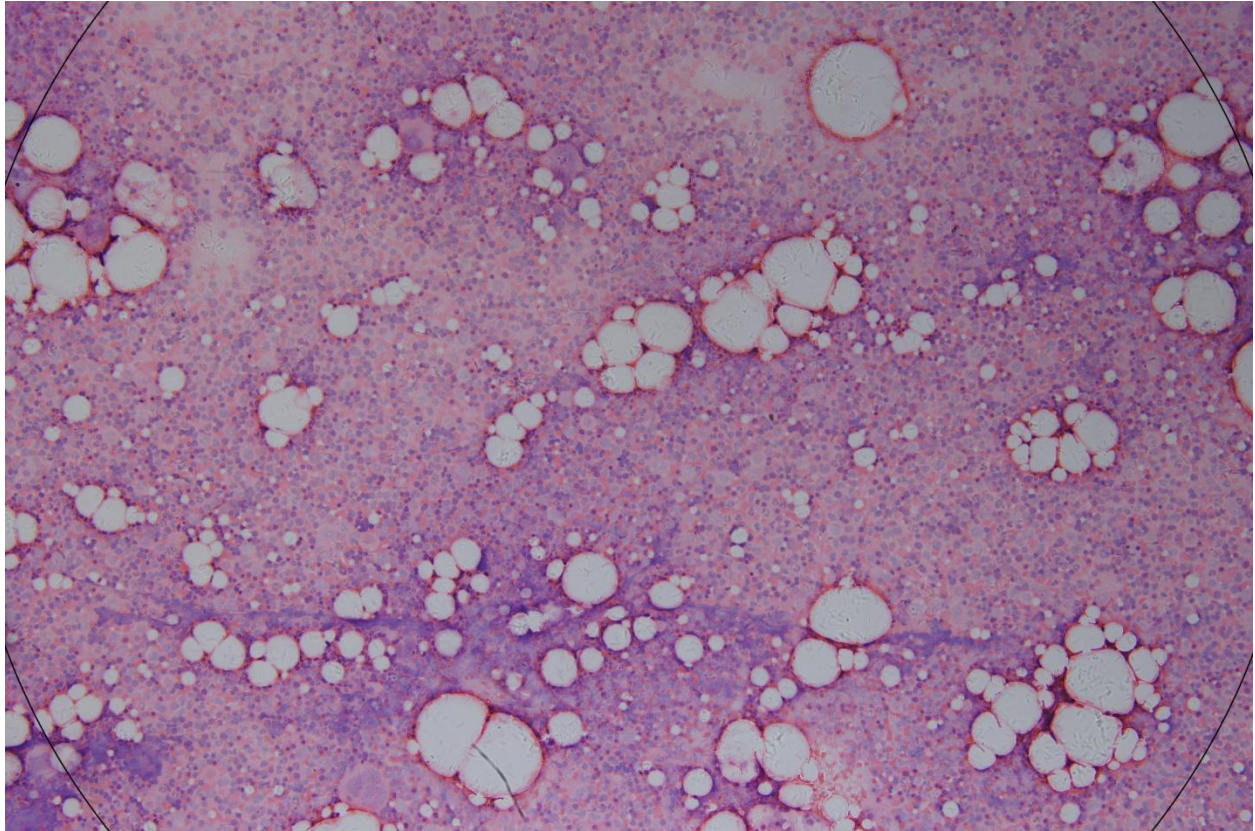
C60-Tube_B and Nikon 20X 0.75 Plan Apo Objective

The standard for performance comparison uses a Nikon 20X NA 0.75 PlanApo objective and the Nikon 200mm tube lens in the **C60-Tube_B**. In all examples below we try to show the same sections of the sample where possible.



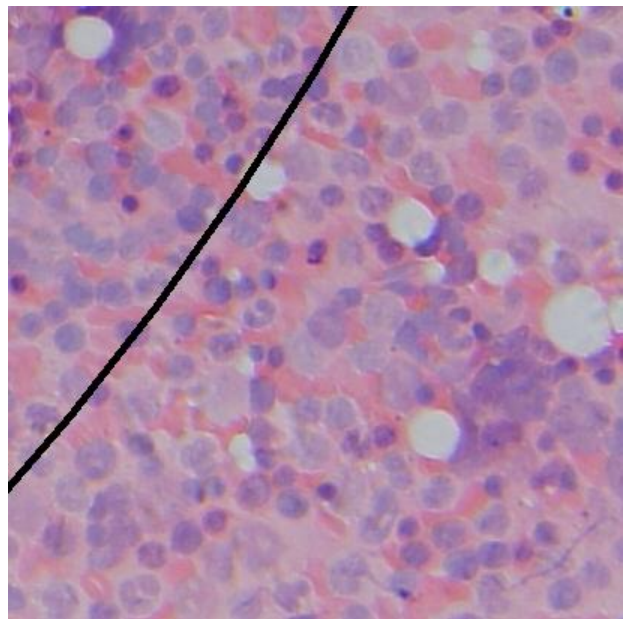
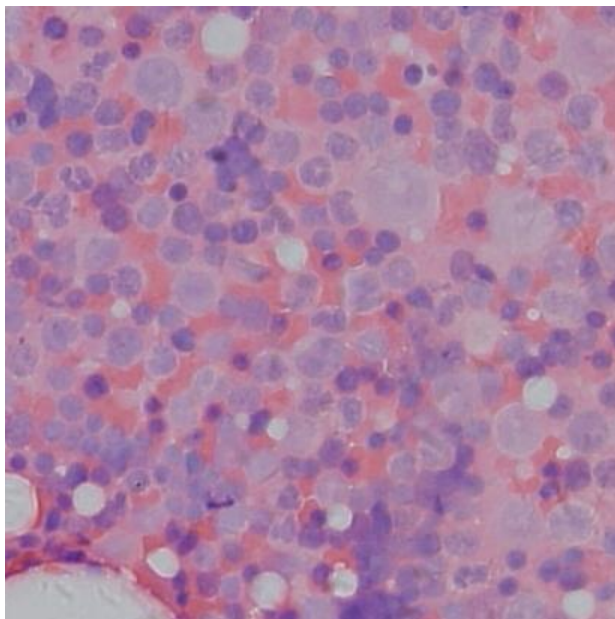
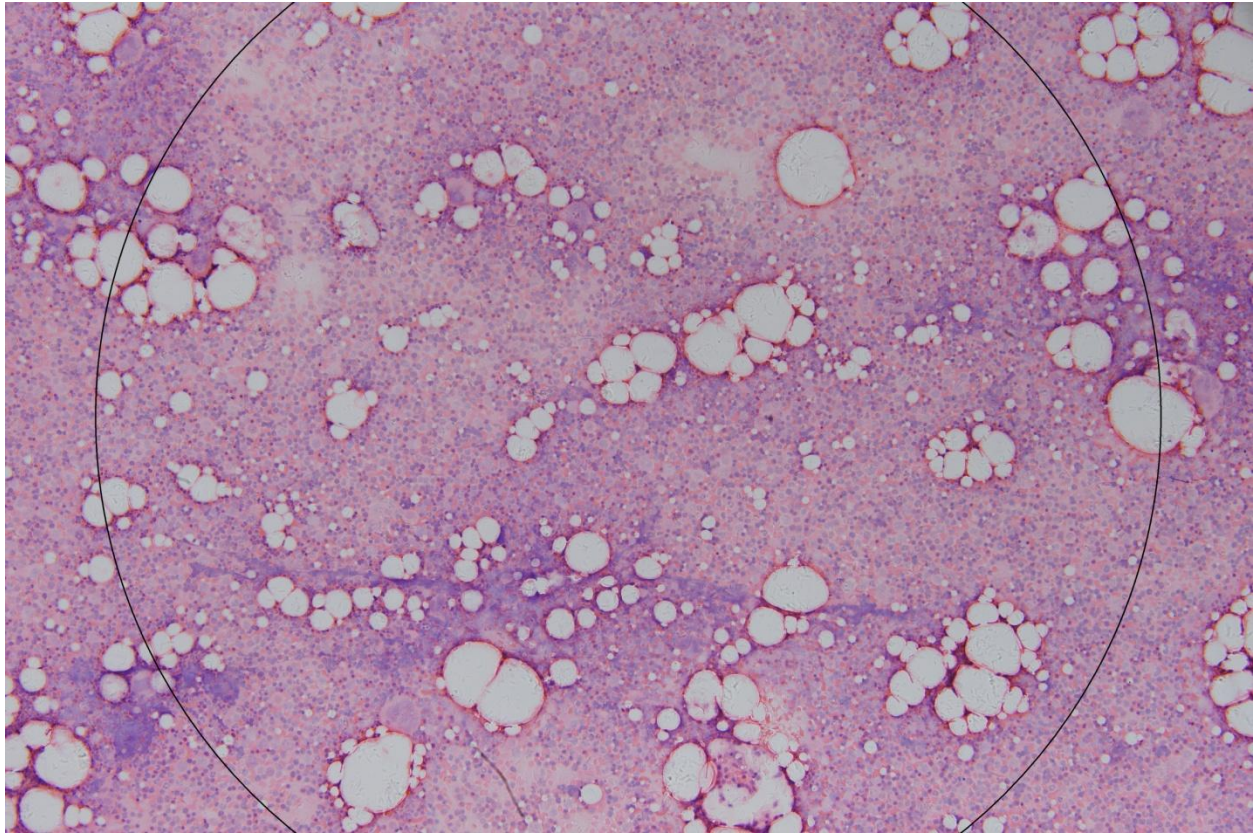
C60-Tube_200 and Nikon 20X 0.75 Plan Apo Objective

How good is the Nikon Tube lens compared to a similar focal length achromatic lens? The **C60-Tube_200** uses a 200mm F.L. achromatic lens, is slightly less expensive and less compact than the **C60-Tube_B**, and delivers the following images.



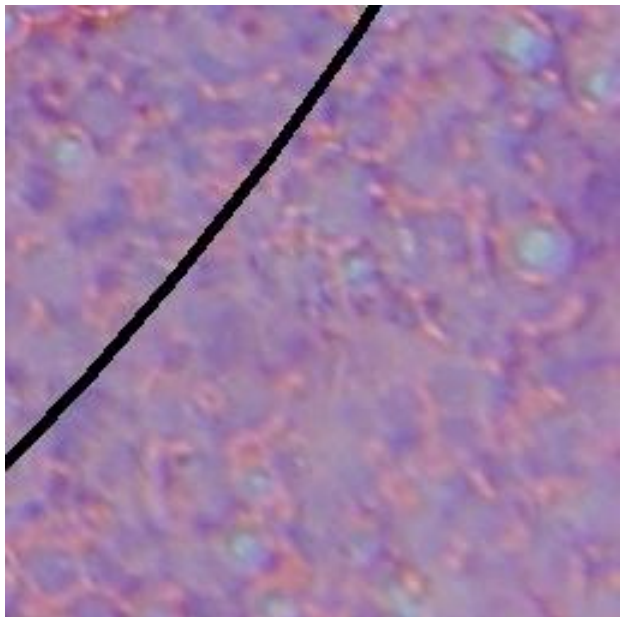
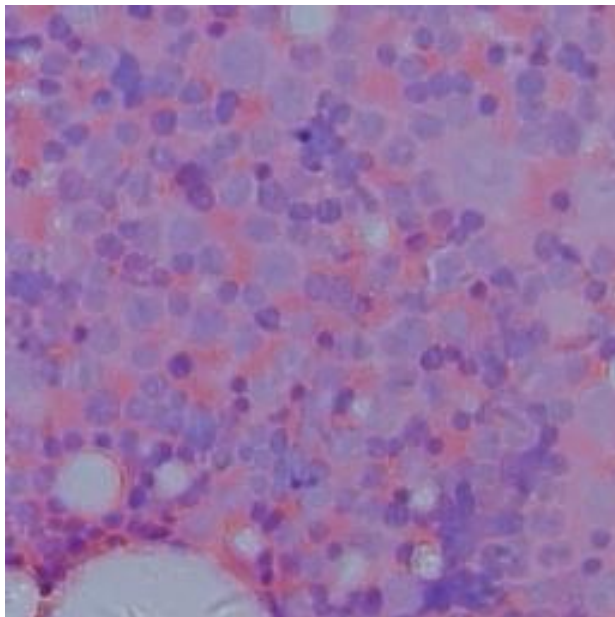
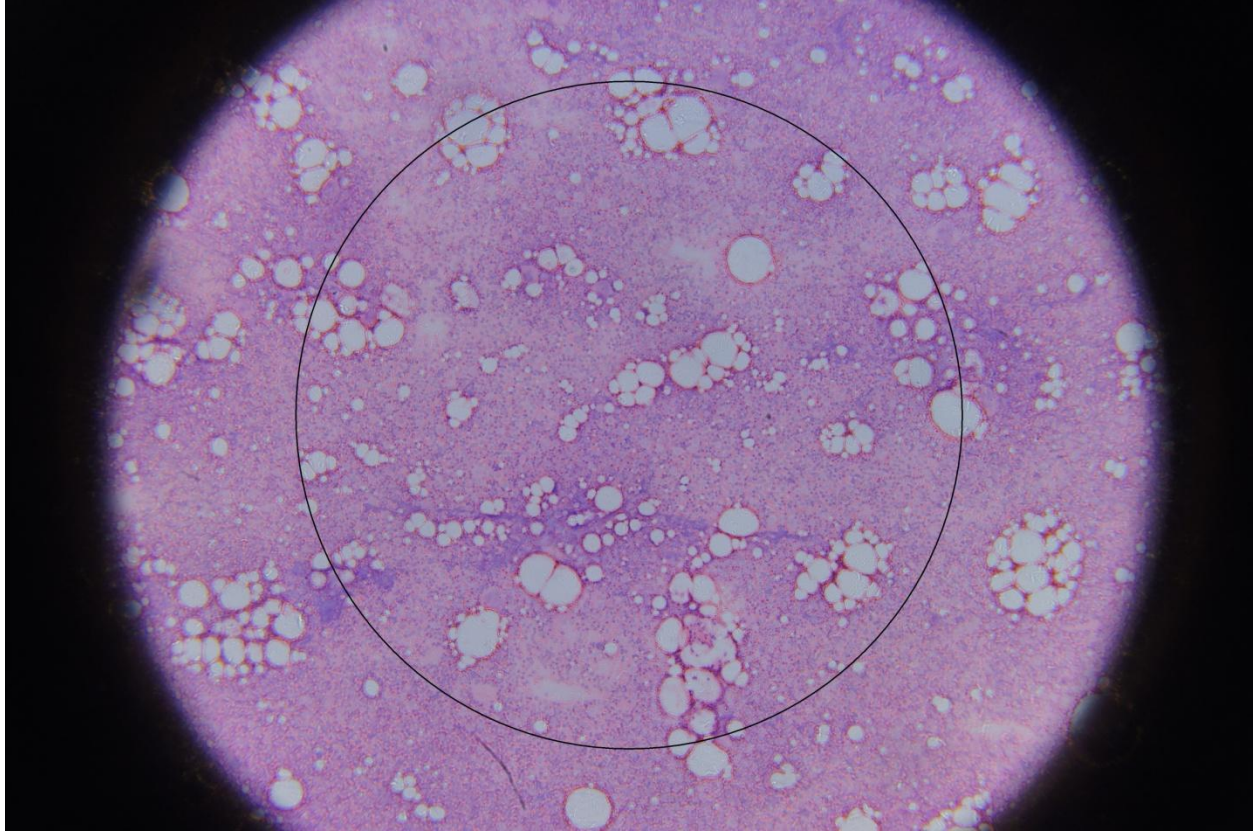
C60-Tube_160 and Nikon 20X 0.75 Plan Apo Objective

The 160mm F.L. Tube lens can be used as a de-magnifier to better fill a small sensor with the available image. This lens maintains a fairly flat image to the 25mm field diameter.



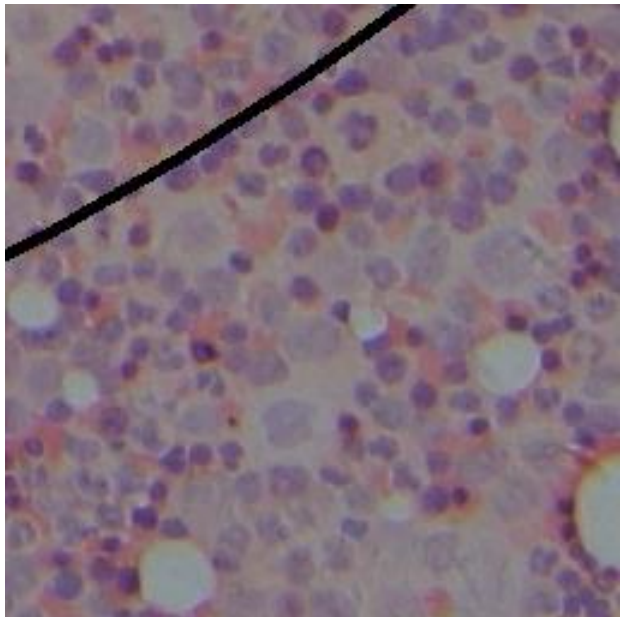
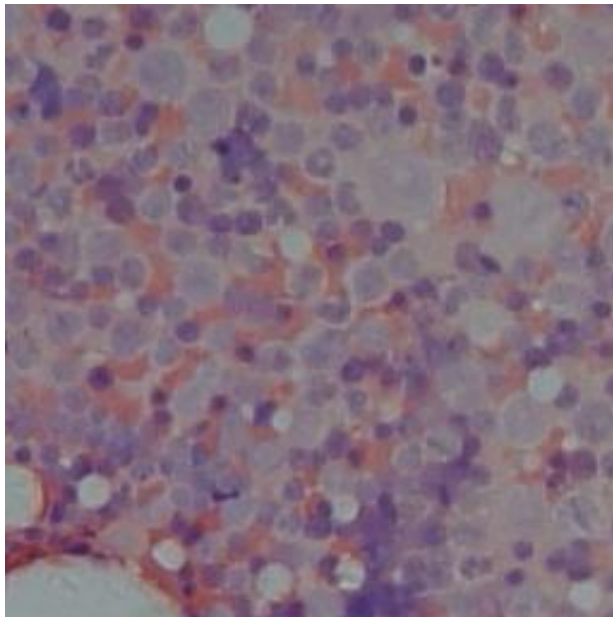
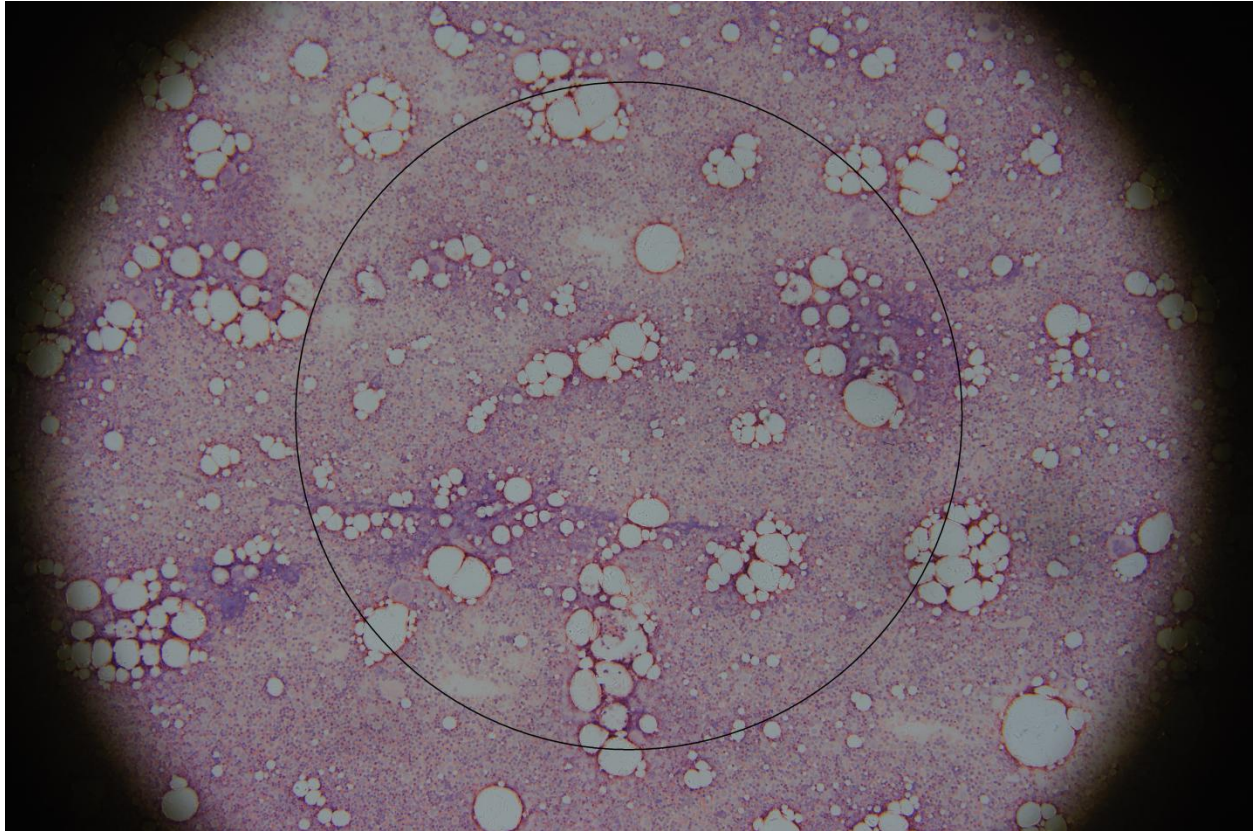
C60-Tube_100 and Nikon 20X 0.75 Plan Apo Objective

A 100mm F.L. achromatic lens cannot be expected to do as well as a longer lens. Nevertheless it can sometimes be helpful to match a wide field of view to a small camera sensor, or it can be used when only the center of the field is being used. **The C60-Tube_100** is also handy for non-imaging applications, such as coupling to CRISP, or as a light source collimator where a more compact and less expensive assembly is called for.



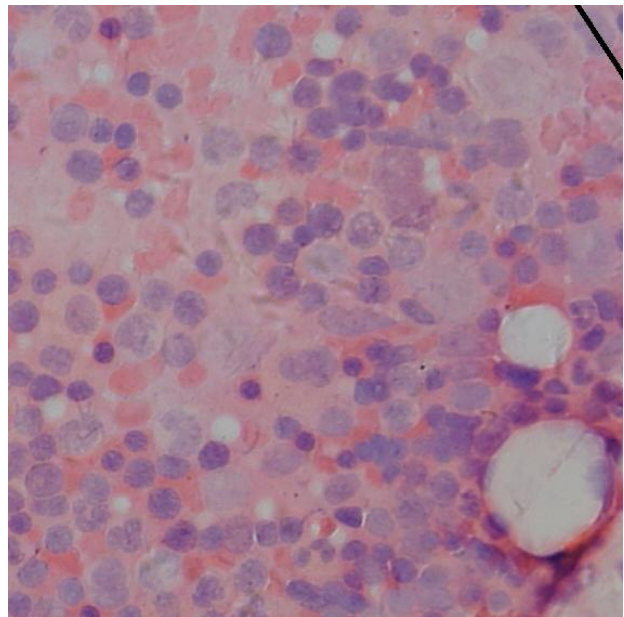
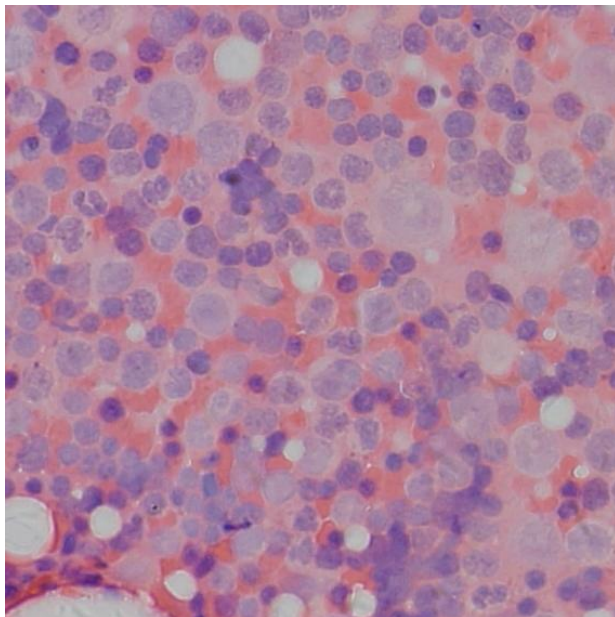
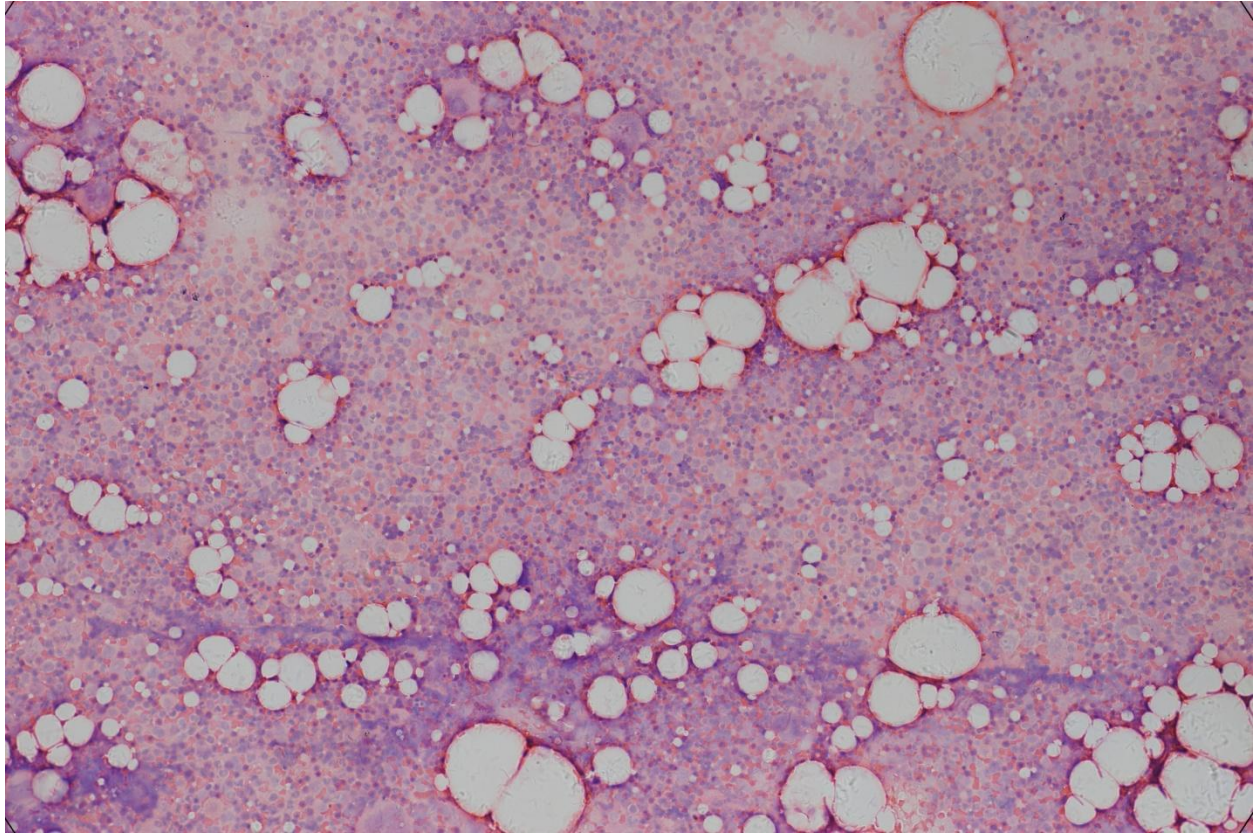
C60-Tube_100D and Nikon 20X 0.75 Plan Apo Objective

Using a dual element design can significantly improve the imaging performance of the 100mm focal length lens. For shorter focal length imaging applications this lens is recommended. (Color differences reflect slightly different exposure and color compensation camera settings.)



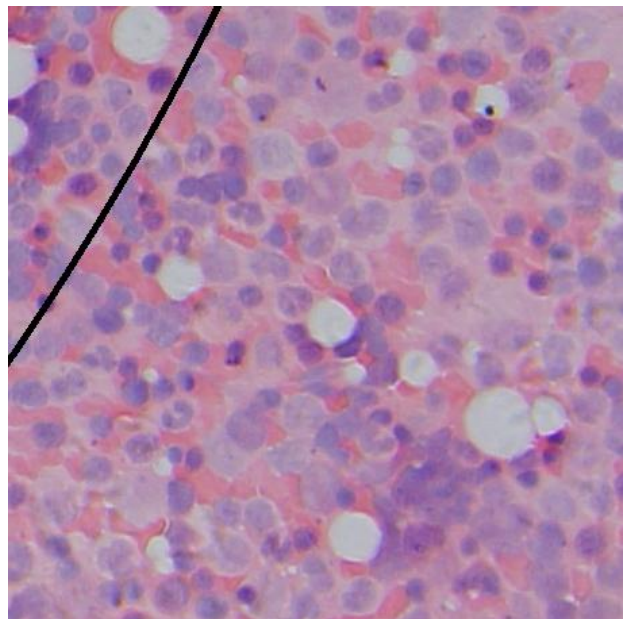
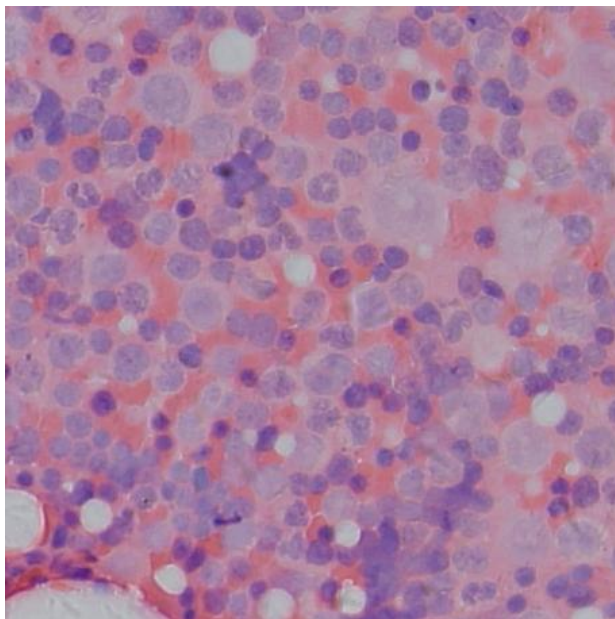
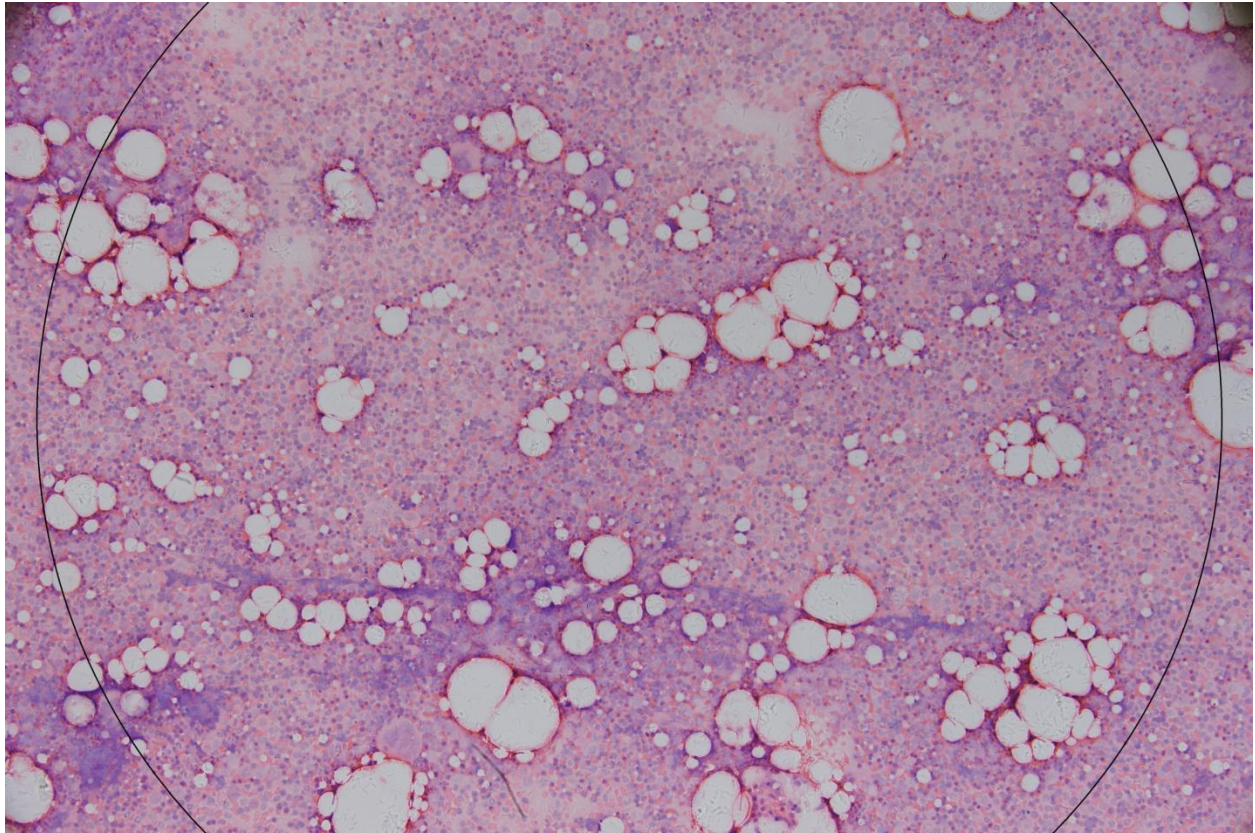
C60-Tube_B and Olympus 20X 0.75 Plan Apo Objective

Here we use a good quality Olympus objective with the Nikon tube lens. Because the Olympus objectives are specified with a 180 mm focal length tube lens, the image size is slightly magnified compared to the 20X Nikon objective. (Note that the 25mm reference is just visible in the corners of the image.)



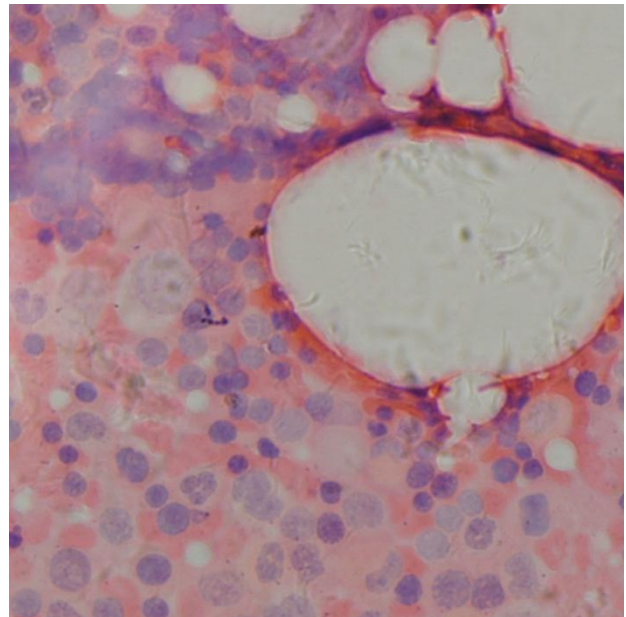
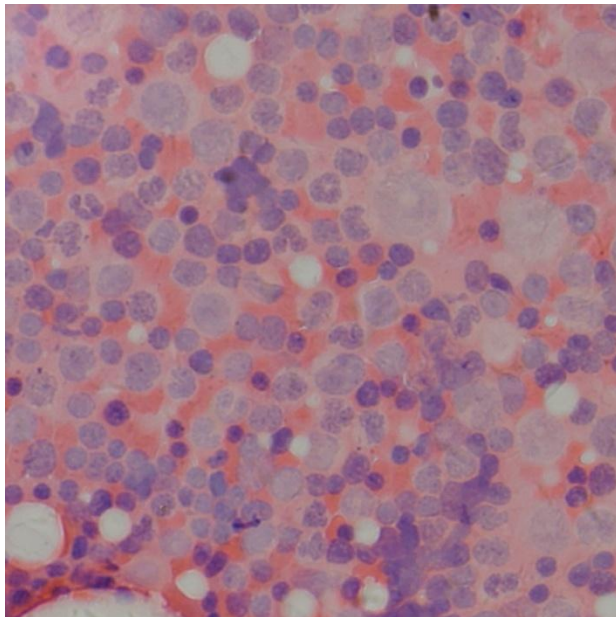
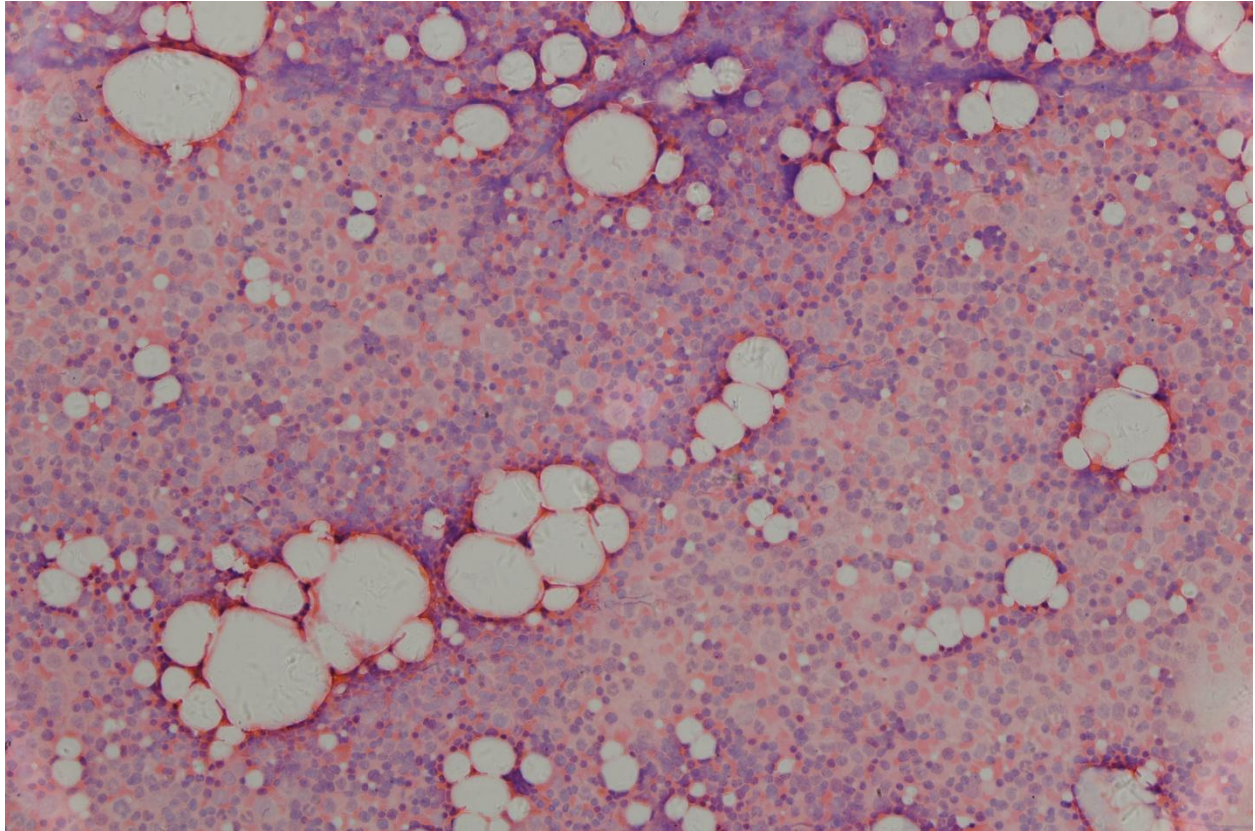
C60-Tube_160 and Olympus 20X 0.75 Plan Apo Objective

With the Olympus objective is designed for a 180mm tube lens, the 160mm tube lens matches this lens nicely to this camera sensor, and provides good resolution to the edges.



C60-Tube_300 and Olympus 20X 0.75 Plan Apo Objective

The 300mm f.l. tube lens can be used when additional magnification of the image is needed on the sensor as might be necessary when dealing with a camera with large pixel size. In this case my camera sensor was not large enough to see to the edge of the 25mm field number of the objective.



Achromatic Tube Lens Ray-Trace Performance

Simple achromatic lenses or ASI's dual achromatic tube lenses have been verified with an optical ray tracing program. For purposes of comparison, ray traces used a 12mm pupil aperture for all lenses. With a larger pupil it is more difficult for the lens to focus all rays as accurately, so performance will be better for objectives with smaller pupils, and worse for objectives with a larger pupil than 12mm compared to what is presented below. There are a few high quality low magnification ($\leq 20\times$) objectives with a larger aperture than 12mm, but most objectives have a smaller pupil.

The field number for the lens is defined as the largest diameter for which a spot can be found where all ray fall within the Airy disk of a 12mm diameter aperture beam. The smallest spot need not be exactly on the focal plane, however.

Part Number	Focal Length (mm)	Field Number (mm)	Airy Spot diameter at image for 12mm aperture (um)	Lens performance at edge of 25mm field circle		With Olympus (180mm tube) Objectives		With Nikon (200mm tube) Objectives	
				Spot focal plane radius (um)	Vignette-free ∞ distance (mm)	Tube lens mag.	Image size of 25mm objective field (mm)	Tube lens mag.	Image size of 25mm objective field (mm)
C60-									
TUBE_300	300	40	40	20	275	1.67	41.7	1.5	37.5
TUBE_200	200	28	27	45	180	1.11	27.8	1	25
TUBE_180D	180	34	24	25	150	1	25	0.9	22.5
TUBE_160	160	20	22	75	140	0.89	22.2	0.8	20
TUBE_100D	100	14	13	60	90	0.56	13.9	0.5	12.5
TUBE_100	100	6	13	500	90	0.56	13.9	0.5	12.5

C60_TUBE_180D and **C60_TUBE_100D** are multi-lens designs that provide superior performance.

C60_TUBE_100 is not recommended for imaging applications.