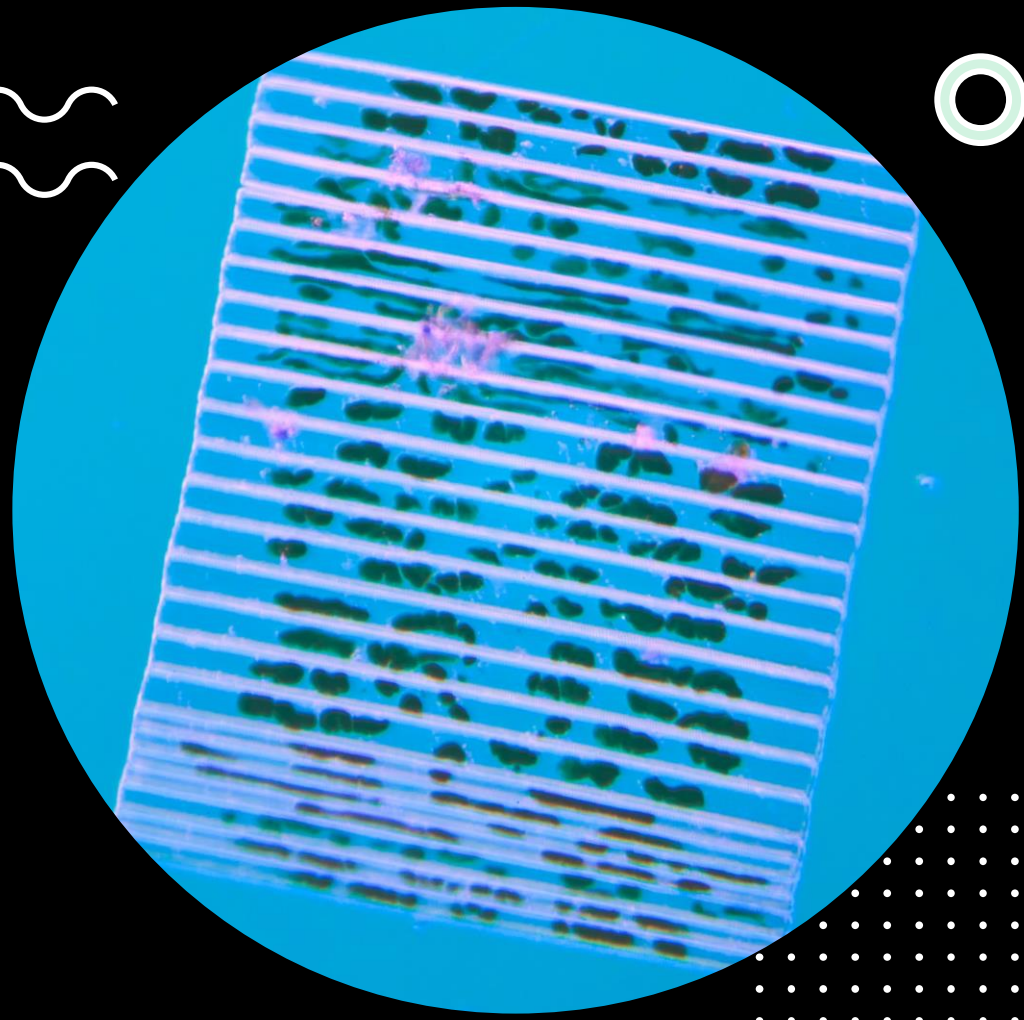
(A guide to pair with this video)

# UPGRADING 160mm MICROSCOPE OBJECTIVES

(for beginner hobbyists)

DIET TOM'S DIATOMS



YouTube

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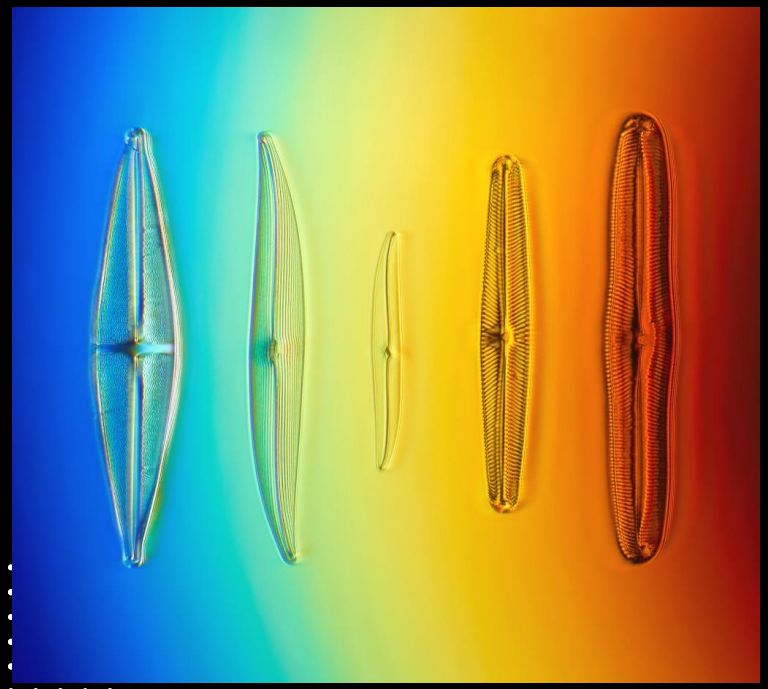
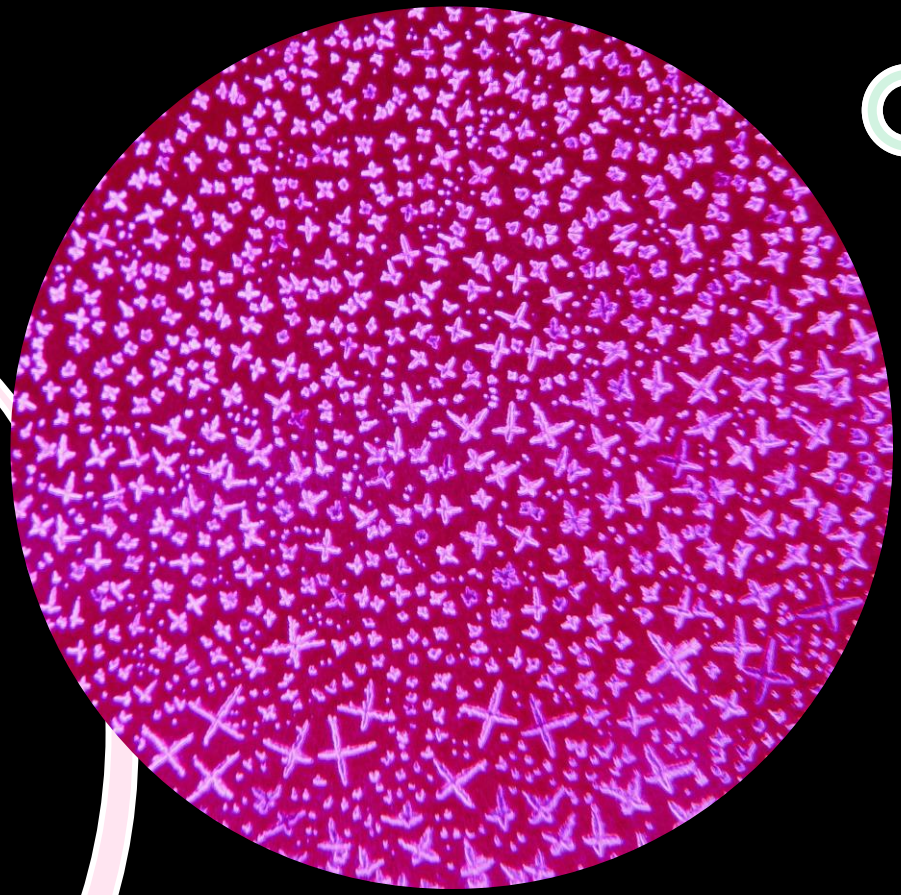
# Agenda

- Intro to the channel
- Assumptions before we begin
- The Current State of Microscopy
- What to Buy (and what not to)
- The Road Ahead



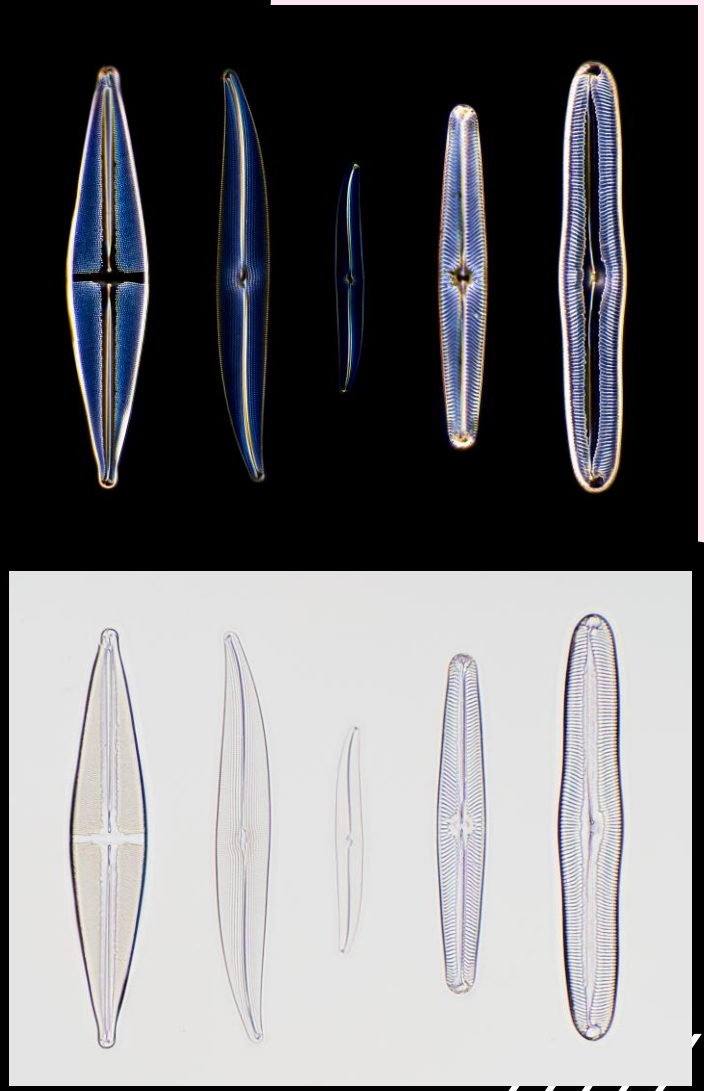
# INTRO

IS THERE A POINT TO THIS?



# THE POINT

I’m an amateur microscopist, engineer, and optics nerd. Microscopy compels me because it draws from nearly every field of optics in some way or another. The microscope is not just a tool for seeing neat critters – it’s the world’s best hands-on optics laboratory for the curious mind! If you dive into microscopy, not only will you have an endless source of entertainment on a rainy day, but also the opportunity to develop an intuitive sense for even the most complex optical concepts!



1. Advance your microscopy
2. Develop your intuition for optics
3. Make cool vids of neat stuff

## CHANNEL GOALS

# ASSUMP-TIONS

(NO ***-MAKING TODAY!)

# MY assumptions about YOU

1. You're ridiculously good looking and smart yet also well grounded and rounded #likeandsubscribe
2. You own a 160mm mechanical tube length compound microscope
   - If your objectives say **160** somewhere on them, then this assumption applies to you
   - If your objectives have the ∞ (infinity) symbol on them, this assumption doesn't apply to you - don't buy any objectives recommended in this guide!
3. Your microscope is of reasonable quality to upgrade
   - MUST HAVE an Abbe condenser with an adjustable iris
   - PROBABLY SHOULD HAVE a bi/trinocular head. If you have a monocular scope, consider upgrading or skipping ahead in the hobbyist roadmap (end of presentation)
4. You're primarily doing some sort of microbe hunting
   - That means you're putting specimens on a slide and smushing them under coverglass
   - If you're doing something a little different, ingest this guide with a few grains of salt

If you already have or are considering an infinity scope, click here!

# MY (cont.) assumptions about YOU

5. You're already pretty okay at using your microscope (IMPORTANT)
   - You don't need to be an expert! But if you're not comfortable bringing an image into focus or adjusting your condenser iris just right to balance contrast and resolution, spend some time improving at this before buying better objectives.
   - You probably have already spent some time playing around with darkfield and/or Rheinberg filters – if not, give that a shot!
6. You are a beginner with a beginner's scope
   - This guide is not intended to be comprehensive and/or nuanced – it's intended to get a beginner to take a step toward advanced amateur microscopy.
   - If you have a 160mm scope from a premier manufacturer (Olympus, Nikon, Zeiss, Leitz/Leica, etc), you should buy lenses made by the same manufacturer. If you have an AmScope, Swift, OMAX, Celestron, Journey to the Microcosmos, etc. – you're the target audience!
7. You want to advance your microscopy
   - I'm assuming that you could at least envision yourself continuing to put time/money/effort into microscopy beyond the purchase of a single lens – once you buy a high-end lens, you're officially a hobbyist (for better or worse!)

# OUT-DATED

(YOUR SCOPE IS)

# The current state of microscopy

- DONT PANIC, but that 160mm microscope you just bought is woefully outdated.
- About 30 years ago, pretty much every major microscope manufacturer stopped making high end 160mm microscopes and optics and switched over to INFINITY-CORRECTED designs
- INFINITY-CORRECTED microscopes represent the current state-of-the-art for microscopy – if a major institution is looking to buy a nice microscope for transmitted light microscopy, they'll probably be buying an infinity scope.

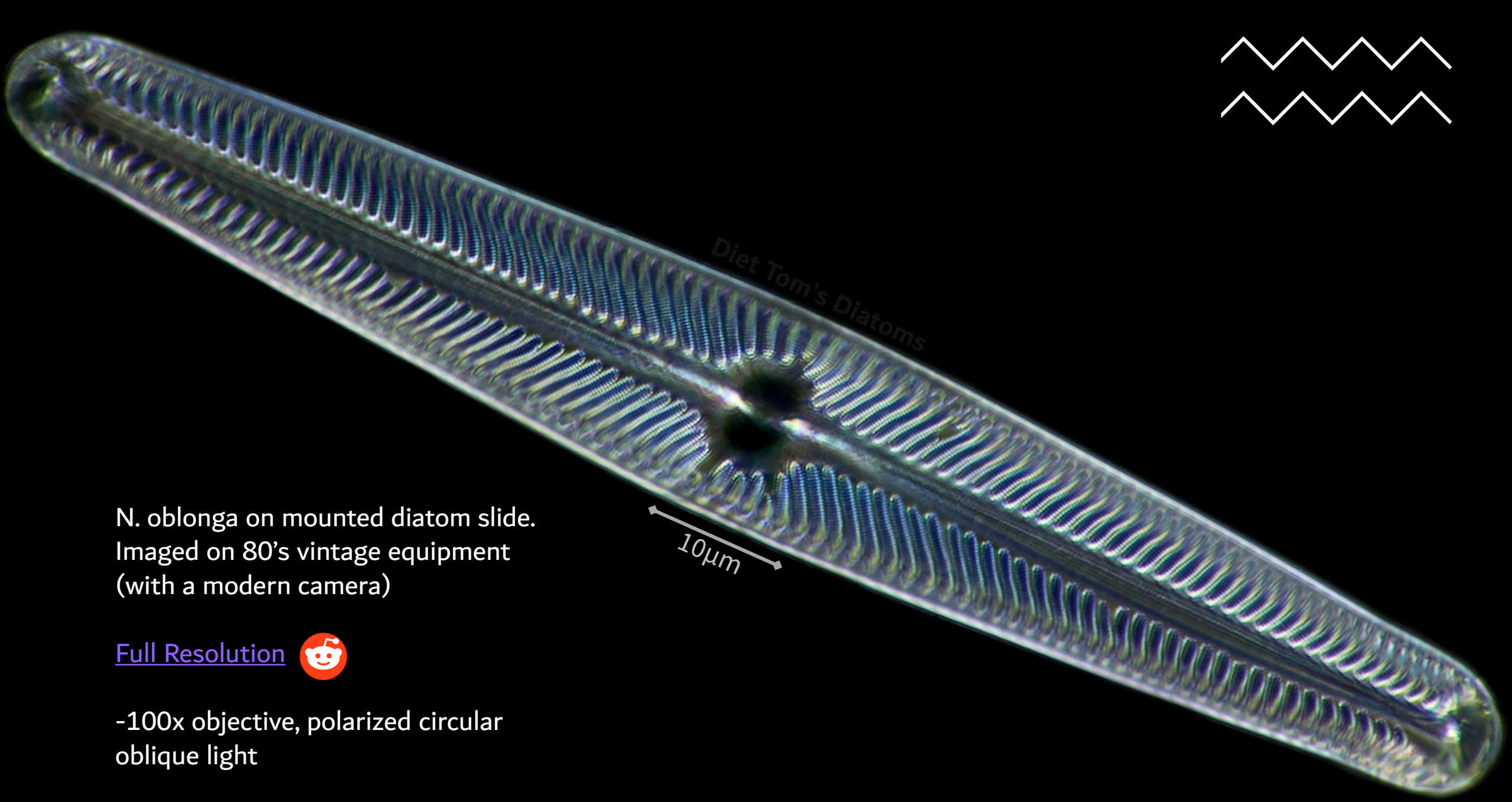
**DOES THIS MEAN THERE IS NO FUTURE FOR YOU AND YOUR 160MM MICROSCOPE?**

# NO!

# NO! (details)

1. Unlike the semiconductor revolution, progress in transmitted light microscopy has been comparably modest – there have definitely been improvements, but optics from 30 or 40 years ago can still produce *exceptional* images and videos!
2. Industry is always slow to adopt – many companies and universities are JUST NOW getting around to swapping out old 160mm microscopes for infinity corrected scopes. That means high quality, good condition 160mm equipment is still making its way to the used market
3. Hobbyists and smaller companies are now the primary market for 160mm optics – lenses and accessories that would have represented cutting-edge technology 30-40 years ago are now affordable on a hobbyist budget!

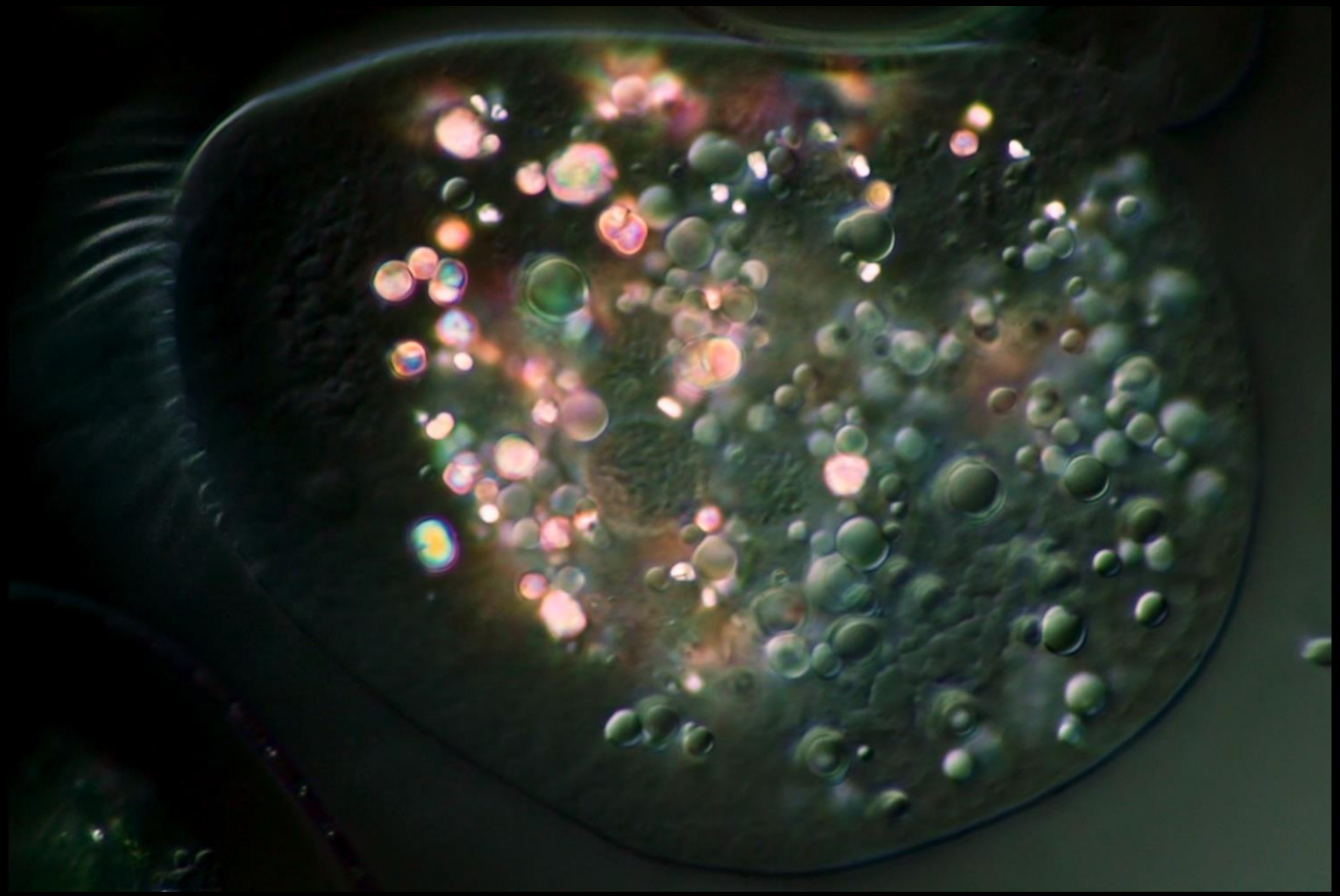
THE 80'S IS WHEN YOU WANNA BE




N. oblonga on mounted diatom slide.
Imaged on 80's vintage equipment
(with a modern camera)

Full Resolution

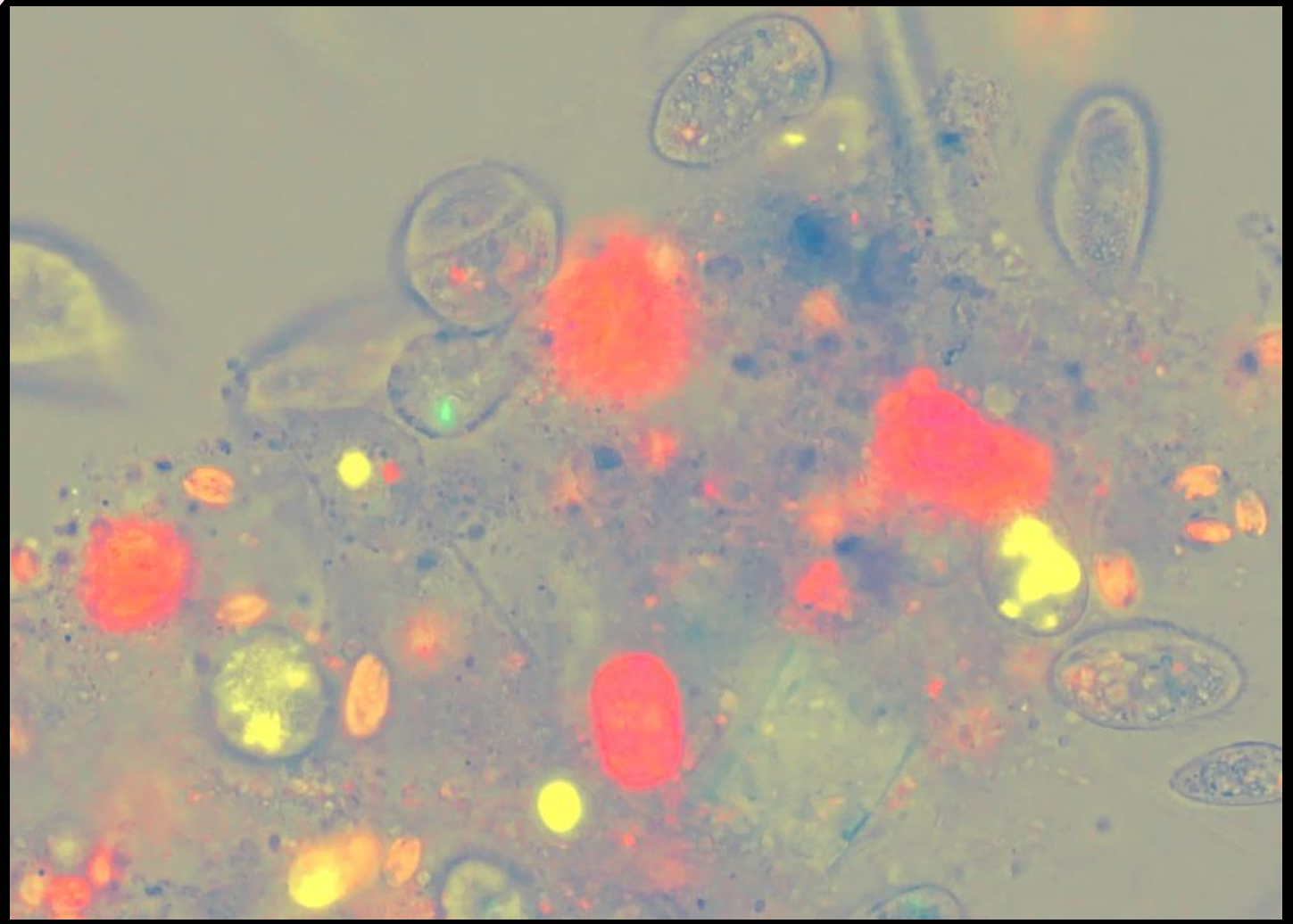
-100x objective, polarized circular
oblique light



Video still of Euplotes sp. using 80's vintage scope, lens, and DIC system

- 100x objective (~1000x mag)

Link to clip



Video still of marine ciliates and algae fluorescing under blue illumination from mercury arc lamp – again, 80's tech

- 20x objective (~200x mag)

Link to clip

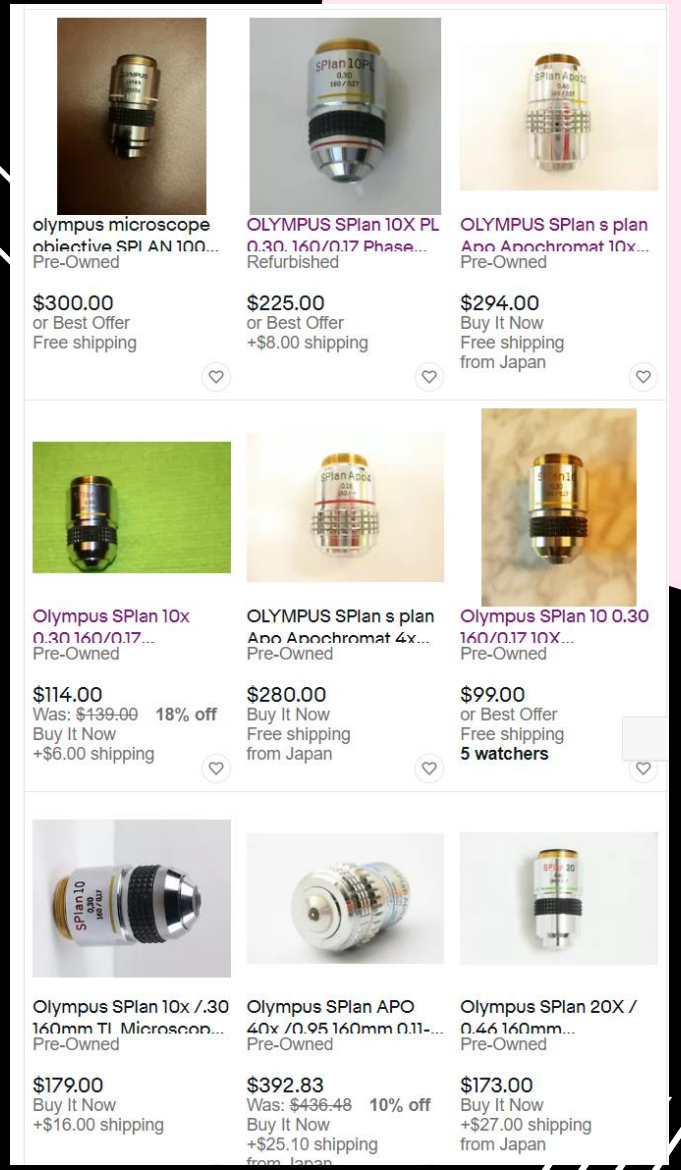
# THE GOOD STUFF

(BUYING NEW OPTICS)

# Where to get used 160mm lenses

If you're in the hobby long enough, you'll find more than a few sources of vintage optics, but your first purchase should probably be from eBay from a seller of reasonable reputation. I'm not an ebay expert and I don't buy/sell optics professionally – all I can say is that if you follow your instincts, read the item description carefully, buy stuff that looks like it's been well-treated, and buy from sellers who seem like they have a desire to maintain a good reputation, you'll usually be fine. If there's a serious quality issue with an optic that a seller overlooked, reputable ones will refund you fully and cover the return shipping.

By the way, if the prospect of buying vintage optics is just not something you're into, then a set of plan objectives from AmScope or another Chinese-origin source is more or less the only option available to you for an upgrade. These will be comparable to the "low end plan achromats" for your scope.



# What not to buy

- Don’t buy Zeiss lenses for your amateur-grade microscope
  - There’s nothing wrong with them, really, but they really need to be on a Zeiss microscope as they require heavy compensation from the Zeiss eyepieces to form a quality image
- Don’t buy phase contrast/DIC lenses
  - These lenses require extra components that are specific to the microscopes they were designed for – you will not get a phase contrast or DIC effect on an amateur-grade scope by slapping one of these lenses on it
  - Phase contrast lenses will often have a “Ph[1/2/3/4]” designation on them
- Don’t buy ULWD or NC/NCG (no coverglass) objectives
  - These lenses are designed for different sample preparations than you’re likely using – avoid them for now
- Don’t buy metallurgical objectives (often with an “M” or “Neo” prefix)
  - These are designed for a microscope outfitted with an epi-illuminator accessory
- Don’t buy PlanApo 40x and 100x lenses (yet)
  - Can they be awesome? Yes. But they can also be difficult to use. Avoid them for now
- Don’t buy 1x or 2x lenses (yet)
  - Low power lenses may require a special low power condenser to fill the image circle with light

For more on this, see Appendix II

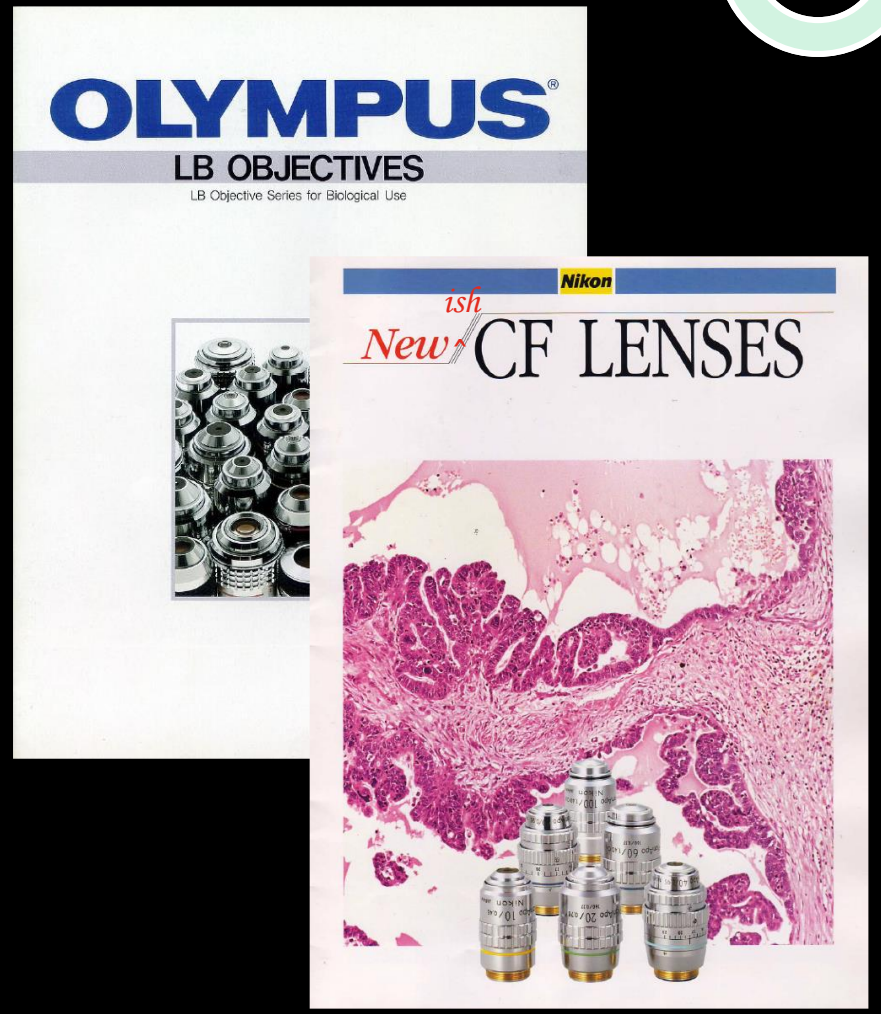
# What to buy

Here's where I make it really easy for you – I'm going to limit you to 29 objectives (15 from Olympus, 14 from Nikon) which I guarantee will produce *better* images than the standard achromats on your amateur scope. Full color catalogs are available (and linked to) for each series. When you look on eBay, closely compare the seller's images to the catalog – if it's not an exact match, it's not the same objective!

These catalogs are also great learning tools – I highly recommend reading the last page of Nikon's catalog! Plus they're full of beautiful photos!

[Olympus LB Objectives]

[Nikon CF N Lenses]



# The basic product structure

Nikon and Olympus have somewhat congruent product lineups. Here's how they generally stack up.

High end plans are better not just for their numerical aperture bump but also better overall secondary corrections

Note: If you're considering upgrading to a vintage Olympus or Nikon scope, I wouldn't load up on low end plans as used scopes are often sold with several of these included for better overall value

| | Rough Price | Olympus Designation | Nikon Designation |
|---|---|---|---|
| **Low-end Plan achromats** | <$100 | DPlan | E Plan |
| **High-end Plan Achromats** | $70-$200 | SPlan | CF N Plan |
| **High-end Plan Apochromats** | $200-$500 | SPlanApo | CF N PlanApo |

Note: Higher end Nikon lenses tend to be more expensive and less common.

# MAJOR UPDATE! READ THIS! (1/15/22)

- As I allude to in the next slide, Olympus objectives generally require correction (in an eyepiece) to achieve a perfect image
- Many amateur microscopes, specifically those with Siedentopf heads (folding binocular heads with a 30 degree angle – Amscope B120, Swift 380B, JttM, etc), tend to incidentally perform correction which causes Olympus objectives to work pretty well! (Conversely, the performance of Nikon objectives is slightly diminished)
- Recently I picked up an amateur grade scope with a 45 degree horizontal sliding head and found that it has a very neutral treatment of the light from the objective
- This means that Nikon objectives perform very well on this scope but Olympus objectives will be severely under-corrected and not look as good as they should
- However, if you use Olympus eyepieces on this head, then you get a nearly perfect image with the Olympus objectives (and possibly a wider field of view as a bonus)
  - Wider (20mm) field Olympus eyepieces: WHK 10x (high eye relief) and WK 10x (normal relief)
  - Normal field (18mm) Olympus eyepiece: CWHK 10x (high eye relief)
  - The "K" is the most important letter – it stands for Korrective!
- I am always doing my best to experiment with every configuration I can find, but there is always the possibility that you'll have a scope where things don't quite work
- If you have issues on your scope, please let me know! The only feasible way to ever make this document truly bulletproof is with YOUR HELP!


Siedentopf head

45 degree sliding head

# Olympus LB

("LB" is for "long boi")

Olympus lenses require compensating eyepieces or photo "eyepieces" to achieve peak performance. They will still perform well on an amateur scope, definitely better than stock objectives, but not quite as well as Nikons.

The reason to buy Olympus lenses is because of the microscope they were principally designed for – the Olympus BH2. The BH2 sold exceptionally well and became a favorite for its balance of value, quality, and ease of use. Today it retains a dedicated hobbyist following and is *by far* the easiest vintage microscope to get into for a beginner. Objectives, accessories, and microscopes from the BH2 era are plentiful and relatively inexpensive.

Choose Olympus lenses if you want to someday own an Olympus BH2 (the 1995 Mazda Miata of microscopes, in the author's mind).

**S Plan Apo**
These objectives compensate for three wavelength of chromatic aberration throughout the visible wavelength range. Thus superior resolution and image sharpness from the center to the periphery of the visual field are obtained. The high numerical aperture provides outstanding resolution. S Plan apochromats are especially suited for photomicrography. These superior quality objectives incorporate the best of advanced Olympus design and production technology and are backed by fine optical microscope making tradition.


**S Plan**
These achromatic objectives are mainly used in high quality microscopes for biological applications. Our development activities emphasized improvements to set new standards in microscope performance and our success in achieving this goal has meet with great acceptance. Excellent optical correction across the entire lens surface makes S Plan Achromats ideal for use in differential interference contrast microscopy and for super widefield observation.
S Plan Achromats open up many new possibilities with larger numerical apertures and longer working distances.

**S Plan FL**
These fluorite objectives (plan semi-apochromats) yield superior image flatness and excellent chromatic aberration compensation. The ultra low magnifications (1X, 2X) of these objectives make them ideal for examination of large specimen areas. They are fully parfocal with other LB objectives. The S Plan FL2X is suitable for super-wide field observations.
Note: These objectives perform best with the BH2-ULC ultra-low condenser.


**D Plan**
D Plan achromatic objectives assure field flatness up to F.N. 20. These achromatic objectives are ideal for photomicrography and are widely used in research, educational and routine work applications.

# Nikon CF N

(The “N” is for “New”! Seriously!)

Nikon’s “Chrome- Free” lenses are the favorites among many microphotographers due to their versatility – they produce a perfect image directly out of the objective so they don’t require corrective intermediate optics to project a perfect image onto a camera sensor.

In the author’s experience, Nikon lenses generally perform slightly better in amateur-grade microscopes than Olympus lenses (the E Plans seem notably better than D Plans). However, a Nikon microscope (such as the Labophot 2) is still required for best performance.

In particular, if you have been eyeing a “Labcam” iPhone adapter as your primary content creation tool, Nikon is a good choice for you as it will produce the best images for adapters which go into the eyepiece tube.

Note: It’s also worth saying here that if you just want a scope that provides quality brightfield imagery and offers similar camera flexibility as Nikon’s CF optics, a Chinese infinity scope is worth considering.

CF/CF N Plan Apochromat Objectives

The chromatic-aberration correction capabilities of these new states of the art objectives extend across the entire visible spectrum to include the g line (violet). They have been improved with larger N.A. and are designed to correct all the various aberrations from the center to the far edges of the field of view. Their superior resolving power, image flatness and color reproduction characteristics serve the most demanding researcher for the most difficult observation or critical photomicrography task.

CF/CF N Plan Achromat Objectives

Offering the performance that was once associated only with Fluor objectives, these objectives avoid the demerits of conventional Achromat objectives to ensure incredible image sharpness over the entire field of view. Superb resolving power due to higher N.A. and high contrast are joined by excellent image-curvature correction, making possible ultrawide-field observation.

E Plan Achromat Objectives

E Plan Achromat objectives provide flatness of field as well as color correction and superior sharp images while at the same time being the affordable choice. Made possible by Nikon's advanced manufacturing techniques, they are rapidly becoming the standard for routine use in today's cost conscious laboratories.

Achromat Objectives

Achromat objectives provide the basic requirements for correcting chromatic aberration using the *c* line (red) and *f* line (blue) standard wavelengths. They are also corrected for spherical aberration and coma. Nikon's CF achromat design improves image flatness, so the sharpness falls off only slightly at the periphery of the field with the image focused at the center. The higher magnification CF Achromats exhibit exceptional flatness for this class of objectives.

Personally, if I were going to spend ~$350 to upgrade my microscope, I'd buy one 10x or 20x PlanApo lens over a set of lower end objectives.

(If you have a set of Rheinberg or darkfield filters, the 10x will usually work easier with those. The 20x on the other hand achieves extremely high detail and is often better suited for photographing or recording single protozoans.)

- Just this guy's opinion

# Misc. thoughts on buying lenses

- If buying multiple lenses, pick one manufacturer and stick to them. This way you can upgrade to one of their microscopes later on and get the best performance out of all of them.
- Numerical aperture is likely to be the most noticeable improvement of any high end lens – the PlanApo lenses really shine because of this. Watch this quick video if you have no idea what I'm talking about.
- Buying better lenses will not automatically upgrade you to producing “Journey to the Microcosmos-level” content! Just as a high end digital camera in the hands of a novice can underperform a low end camera in the hands of an expert, there is still much to learn and consider in terms of your whole content creation pipeline, illumination techniques, and sample preparation. Microscopy is a skill that improves with practice!
- I’d recommend starting off with just one or two lenses – if you really want to load up on premium glass, then you should also pick up a used vintage microscope as it’s likely to be a fairly modest additional cost.

# THE ROAD AHEAD

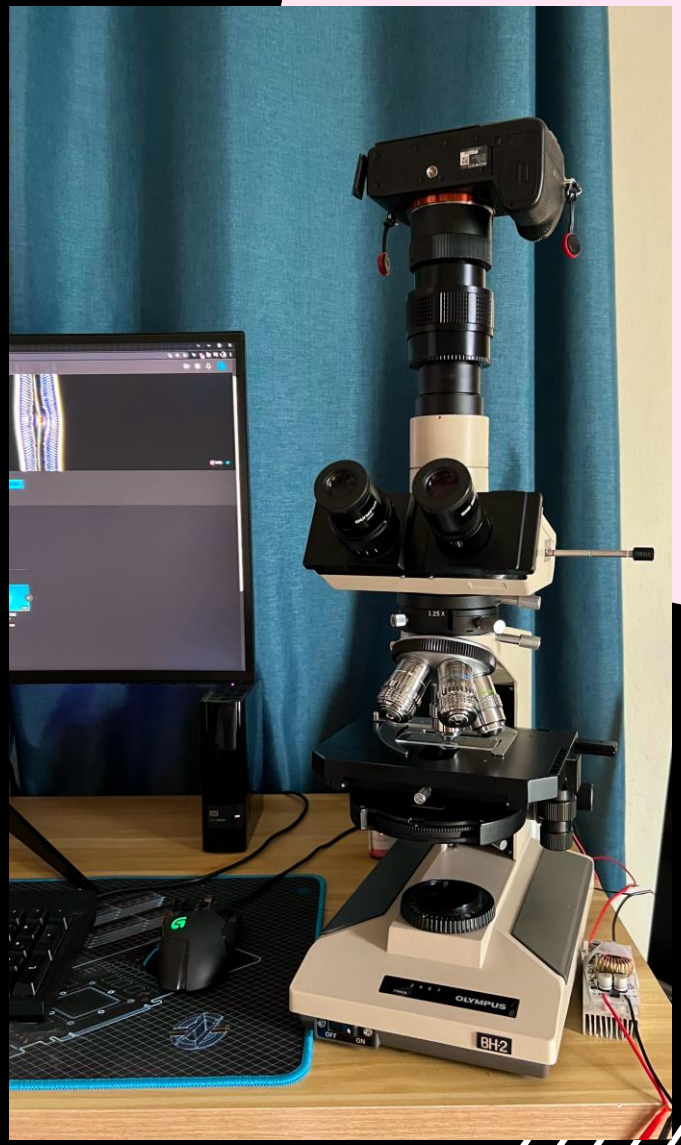
(should you choose to walk it)

# Advanced amateur microscopy

An amateur-grade 160mm microscope can produce amazing imagery, especially if you research, practice, and experiment with different illumination techniques. And adding on some high end lenses can really kick it up a notch!

But if you decide that you want to keep progressing and building on the hobby, then one path that I can recommend is picking up a clinical-grade 160mm vintage microscope – such as the Olympus BH2 that I use. Properly refurbished, you'll find these microscopes much more enjoyable to use and work with. They're simple, sturdy, and flexible, and can be purchased in refurbishable condition for very low prices. If you decide you're really all-in on the hobby, they can be outfitted will all sorts of upgrades from epi-fluorescence to phase contrast and even DIC.

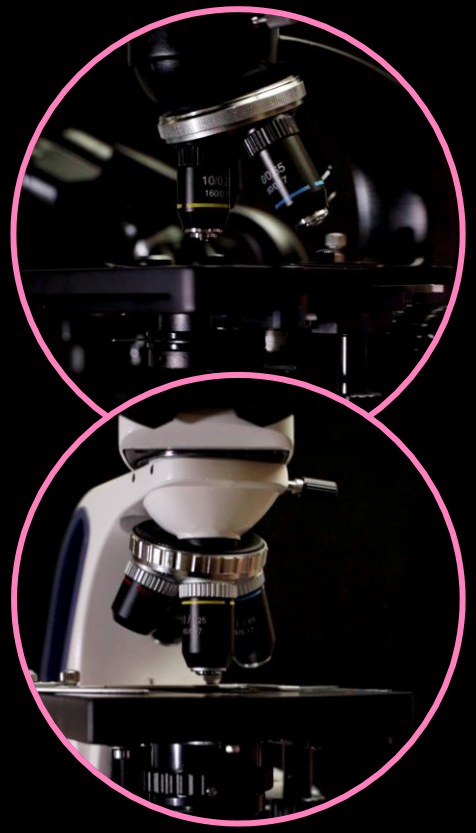
If this sounds interesting to you, here is my proposed roadmap for progression in the hobby...

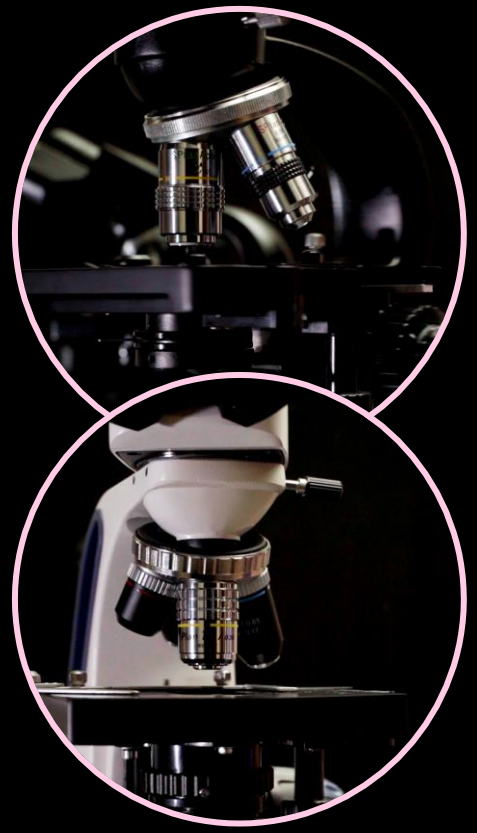


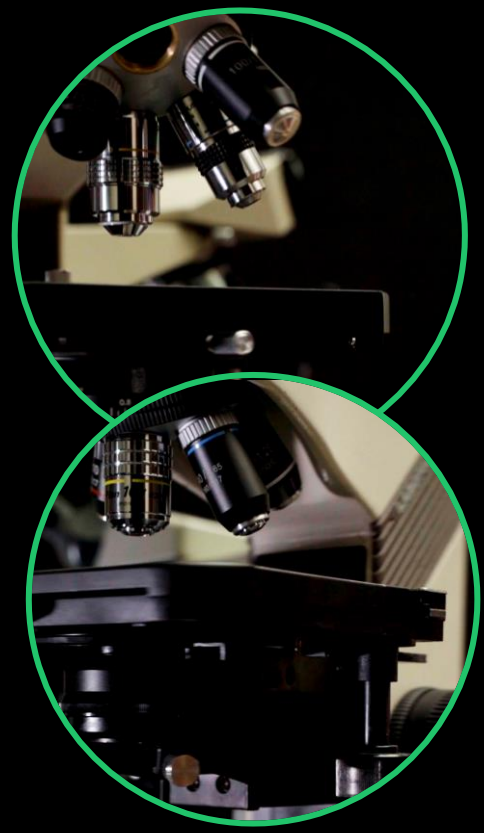
(My main scope for reference)

# Advanced Amateur Microscopy Roadmap (160mm)

Amateur Scope







Advanced 160mm Clinical Scope

New optics

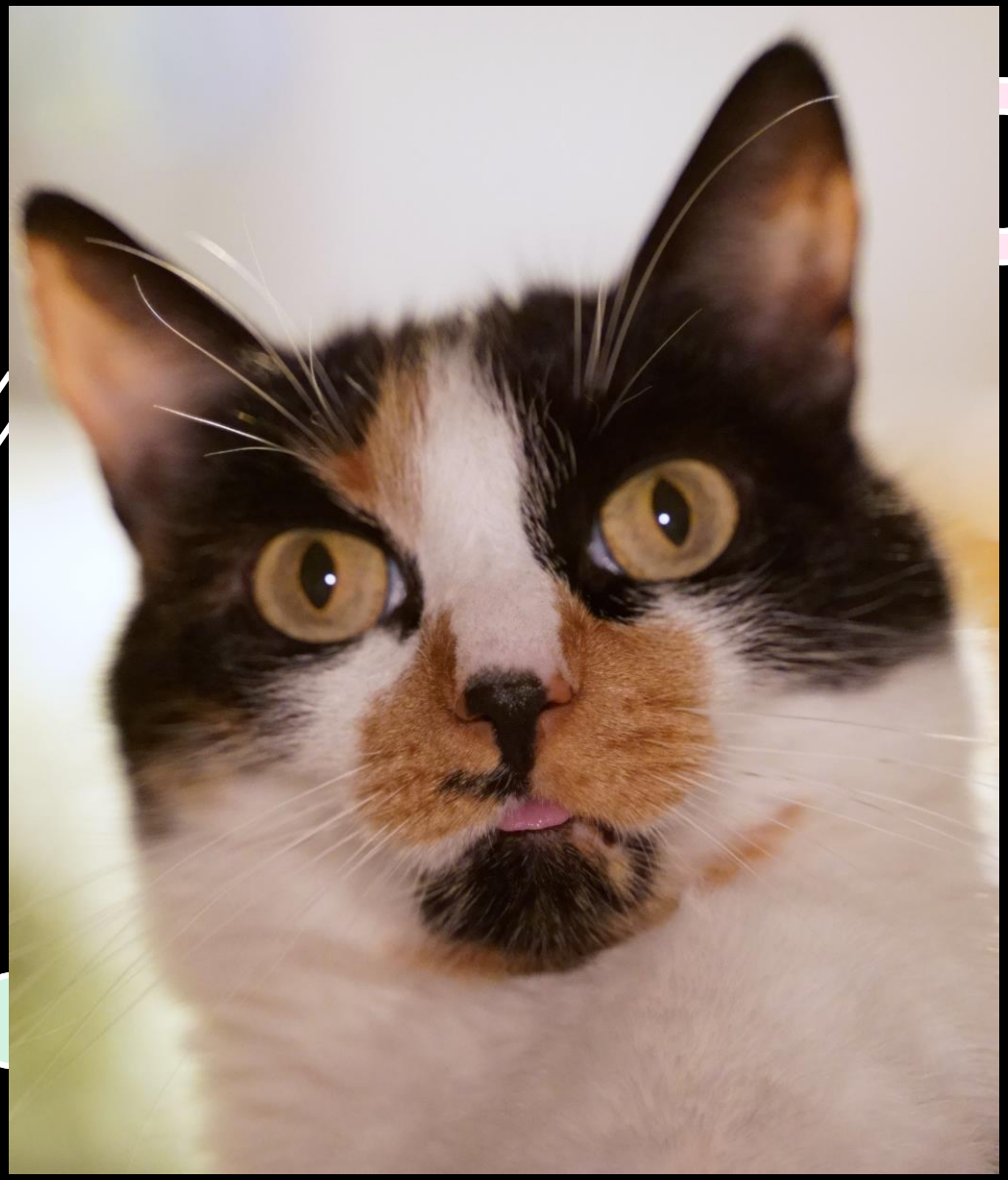
Move optics to clinical grade scope

New optics

# ENJOY YOUR SCOPE!

Questions/comments:
diettomsdiatoms@gmail.com

(Kinsey)------>



# APPENDIX

# I. Infinity Scopes

A modern infinity scope will produce better imagery than a comparably outfitted vintage 160mm scope. Advances in optical design methods, anti-reflection coatings, and manufacturing techniques enable modern infinity corrected optics to achieve higher performance in practically every metric than even the best 160mm optics. Even low cost Chinese-origin infinity scopes, such as those manufactured by Motic, produce truly great imagery. Something like a used Motic BA310 for under 500 dollars can be a great buy if you just want a really nice microscope but don't plan on upgrading too much in the future.

The only problem with infinity microscopes is that they cost quite a lot more than comparable 160mm vintage microscopes. Every upgrade is 2-10x more expensive and you're competing with well-funded institutions as a potential buyer. Do I want to own an infinity corrected system some day? Heck yes I do – they're awesome! But the realm of 160mm vintage equipment allows me to more fully explore the range of optical methods used in light microscopy at my current budget.

If you already bought an infinity microscope, you should keep it! As time goes on, there may be more opportunities for infinity upgrades at the hobbyist level. Motic is currently making apochromatic objectives (still not cheap or plentiful used) and other Chinese manufacturers are joining the fray to produce less expensive high quality systems. They're still not cheap, but they're cheaper and the used market might start to hot up in the next several years.

# II. Considerations for high mag lenses

In each of the catalogs I've linked to in this presentation, there are tables near the end of the document detailing technical specifications for each lens. Let me call your attention to the SPlanApo 40x entry as an example. This lens has a working distance (space between coverglass and lens) of just 130 microns! And that is only for imaging subjects immediately below the coverglass – if you try to focus on deeper specimens, you may crash the objective into the slide! Moreover, this lens will exhibit awful spherical aberration unless the correction collar is set correctly. For these reasons, I don't recommend this lens or other high mag, high numerical aperture lenses for a beginner.

The SPlan 40x has a working distance of 500 microns and is much more usable for general purpose microbe hunting. The 20x SPlanApo achieves the same numerical aperture (i.e. level of detail) as the SPlan 40x over a wider field and also has a perfectly usable working distance of 550 microns.

| Magnification | | Numerical Aperture | Working Distance mm | Focal Length mm | Remarks |
|---|---|---|---|---|---|
| **S Plan Apochromatic** | | | | | |
| S Plan Apo | 4X, dry* | 0.16 | 9.83 | 36.71 | S.W. |
| | 10X, dry | 0.40 | 0.55 | 16.92 | S.W., Spring-loaded. |
| | 20X, dry | 0.70 | 0.55 | 7.68 | S.W., Spring-loaded. |
| | 40X, dry | 0.95 | 0.13 | 4.18 | S.W., Correction collar (0.11 ~ 0.23), Spring-loaded. D.I.C. (with UCD) |
| | 60X, oil* | 1.40 | 0.12 | 2.80 | S.W., Spring-loaded. |
| | 100X, oil | 1.40 | 0.15 | 1.62 | S.W., Iris diaphragm, Spring-loaded. |

# III. Olympus BH2 Resources

I'll definitely be talking about my primary scope - the Olympus BH2 - more as this channel moves forward. While I won't be restricting myself to it as my only vintage scope, it's likely to be my workhorse, and I hope I can help other folks get into it as well. If you're a self-starter with a decent mechanical aptitude and want to make the jump to the BH2 right away, here are some critical resources:

Alan Wood's website: http://www.alanwood.net/olympus/microscopes.html

Carl Hunsinger's YouTube channel:
https://www.youtube.com/channel/UCkuGuiMZZmkDLbRAnj8CxuA

Alan and Carl together have compiled just about every scrap of information about the BH2 known to humanity. Carl repairs BH2s as a hobby/side gig and has written immensely detailed repair/maintenance guides for them (available on Alan's website). He has also recorded the refurbishment process for many of the BH2 subsystems on his YouTube channel. Their commitment to the hobby was what made me confident enough to make the leap myself!

The only piece of buying advice I'll make at this time is, if possible, find a local seller and go check out the scope in person! Often you can negotiate a better sale price in person as well.