

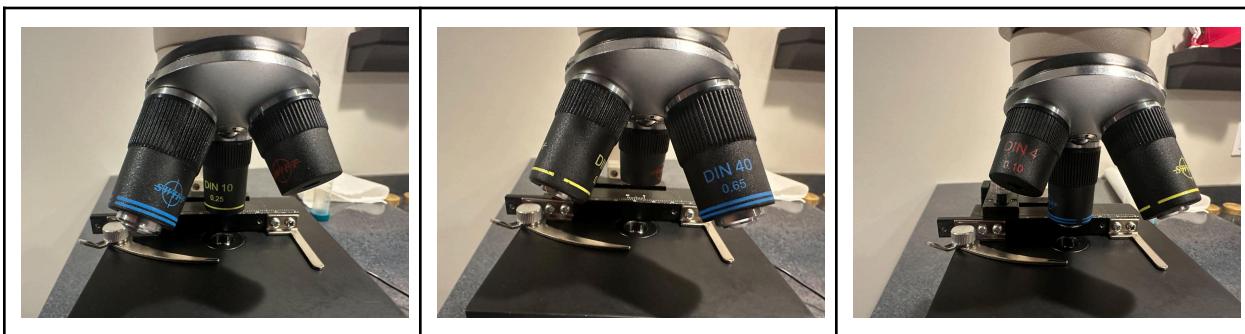
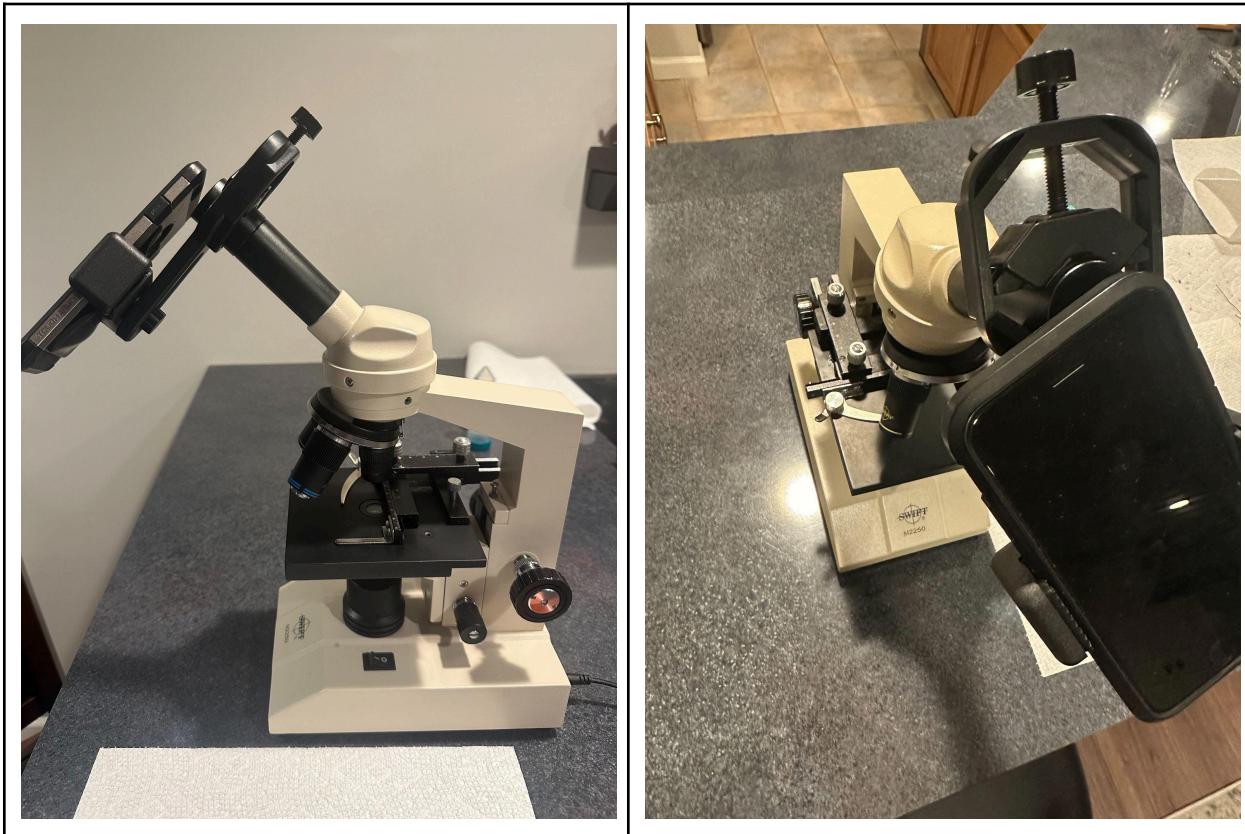
Freshwater Rotifer and Protozoa Object Detection and Image Classification Project

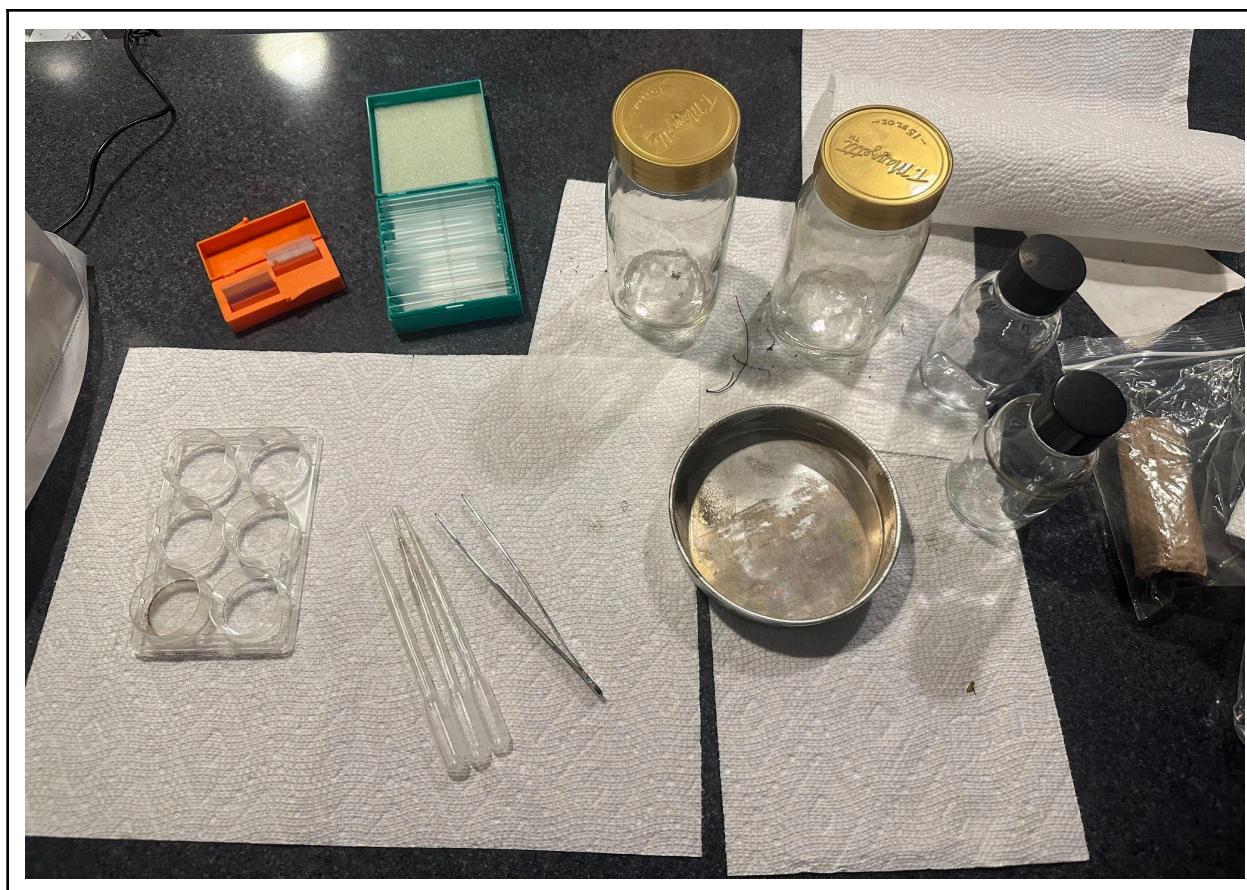
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Our world is bigger and smaller than we could ever imagine. Microscopic organisms do more for us than anyone could ever imagine. Microorganisms play a crucial role in our environment and are critical to the survival of our ecosystem. Suppose you have ever been to a freshwater pond, lake, or stream and wondered how that ecosystem survives. In that case, it is small thanks to the critical microorganisms Rotifer and protozoa, which live within the water, clean it, and provide substance for the creatures in the environment.

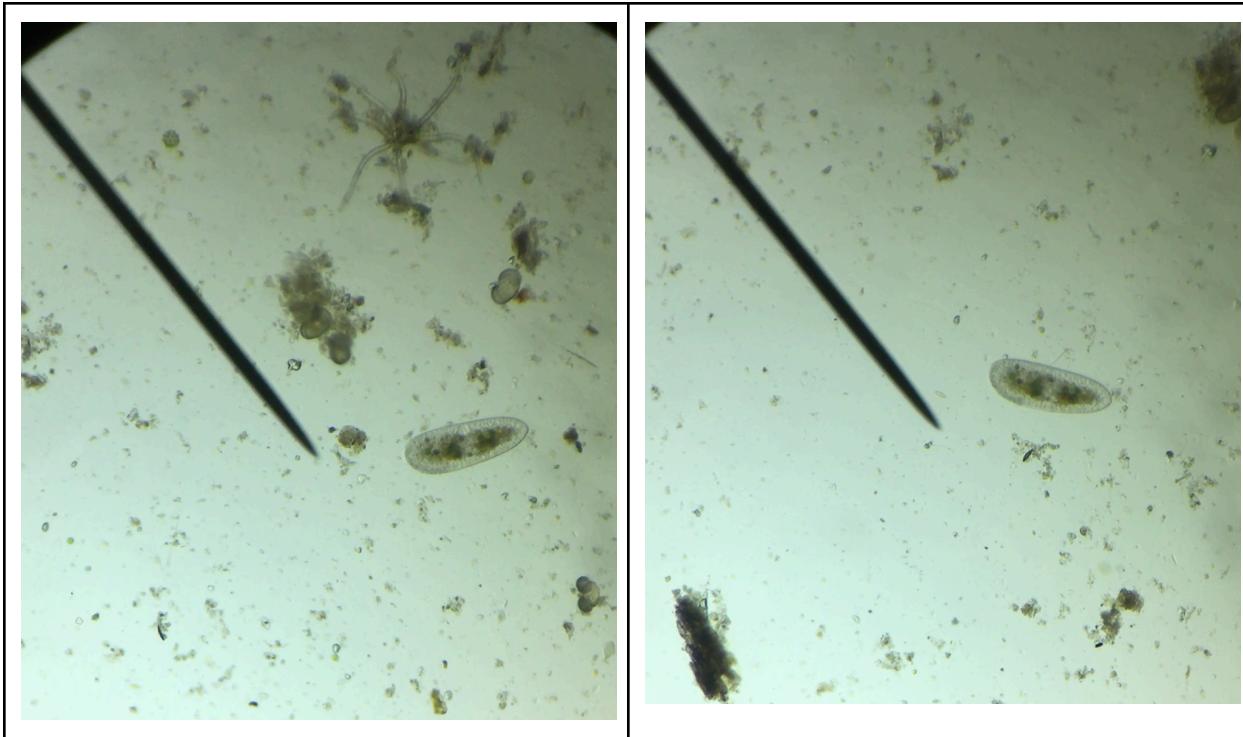
A single drop of water can potentially contain a large ecosystem of its own on a microscopic scale. The often forgotten topic of microorganisms, including plankton, Daphnia, Rotifer, Protozoa, and bacteria, can all survive within a drop of water and live off the organic plant matter that contains the necessary nutrients that each of these microscopic organisms need to survive. In particular, the Rotifer and Protozoa both play a crucial role in keeping the pond's ecosystem healthy and providing a necessary food source in which other invertebrates can live. The Rotifer and Protozoa eat the decaying organic matter and bacteria and release nutrients when the bacteria is consumed. They also play an instrumental part in treating the water waste that accumulates in the pond, allowing the freshwater to remain as healthy as possible and allowing all different animals to stay healthy and strong.

The six microscopic organisms we will be using, discovering, and labeling for both the object detection and image classification models are Paramecium, a small unidentified Protozoa, Rotifer, Spirostomum, Stentor, and Vorticella. There are millions of different species of microorganisms, so I must limit the research project to cover a select amount of Rotifer and Protozoa to create a model that can detect and classify them effectively.

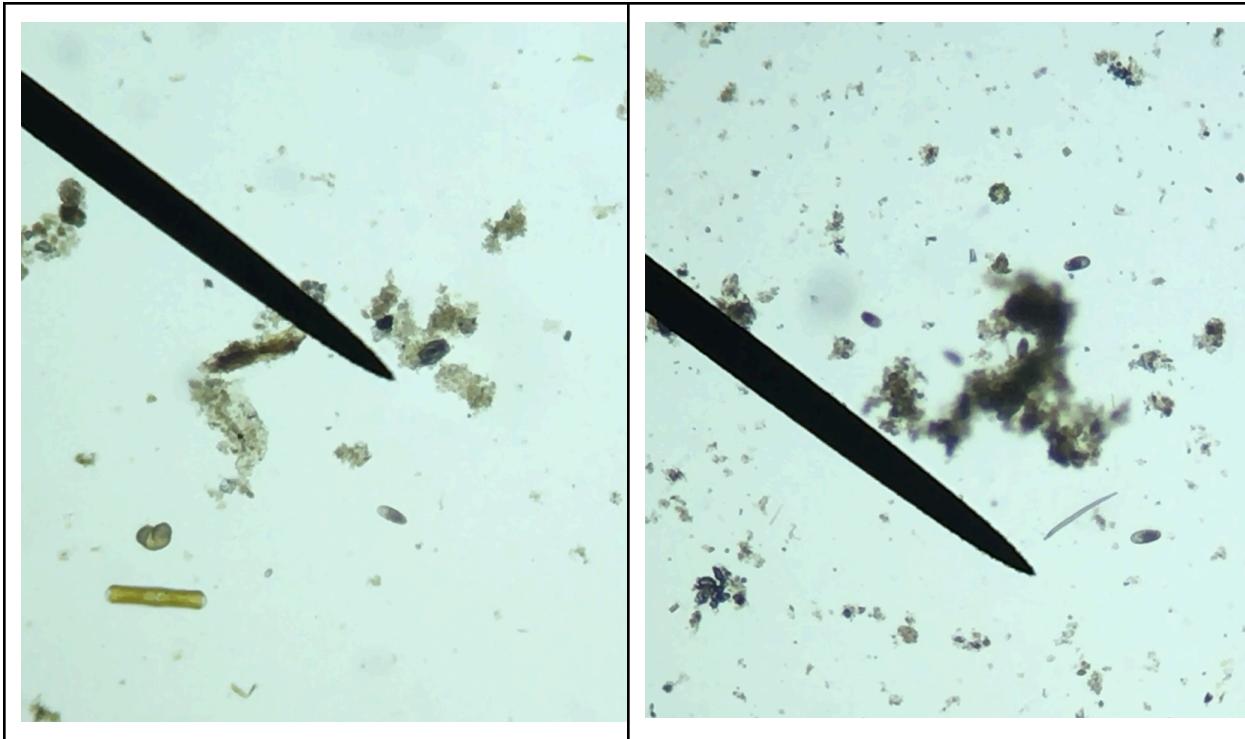




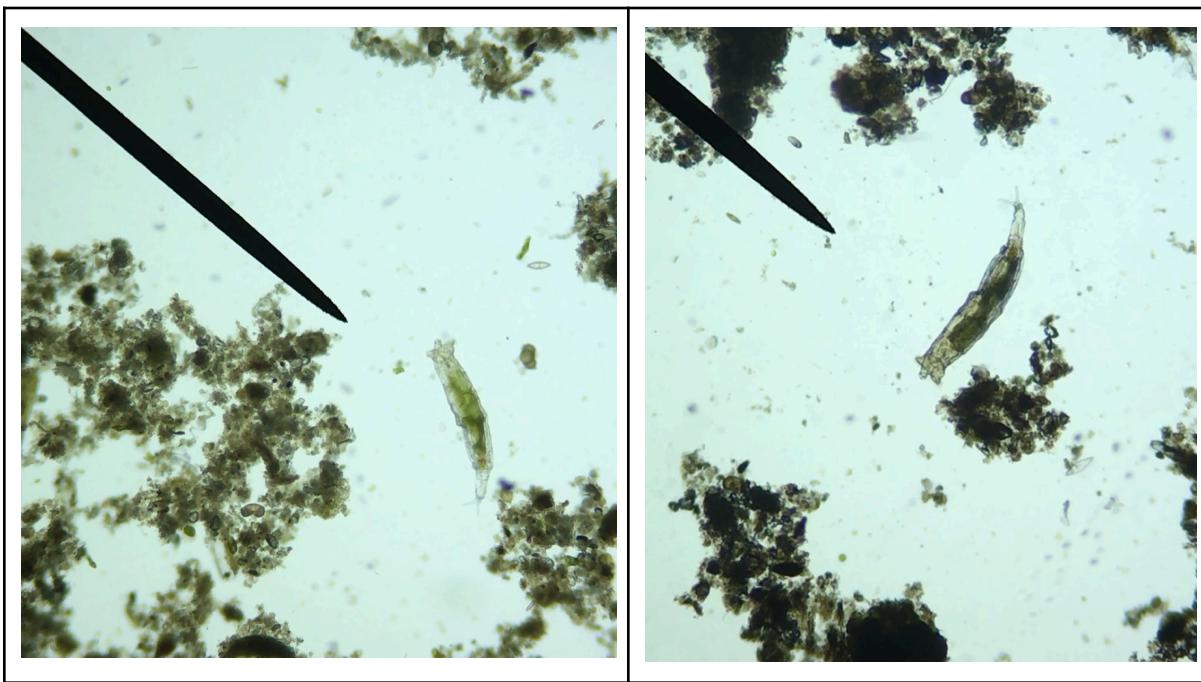
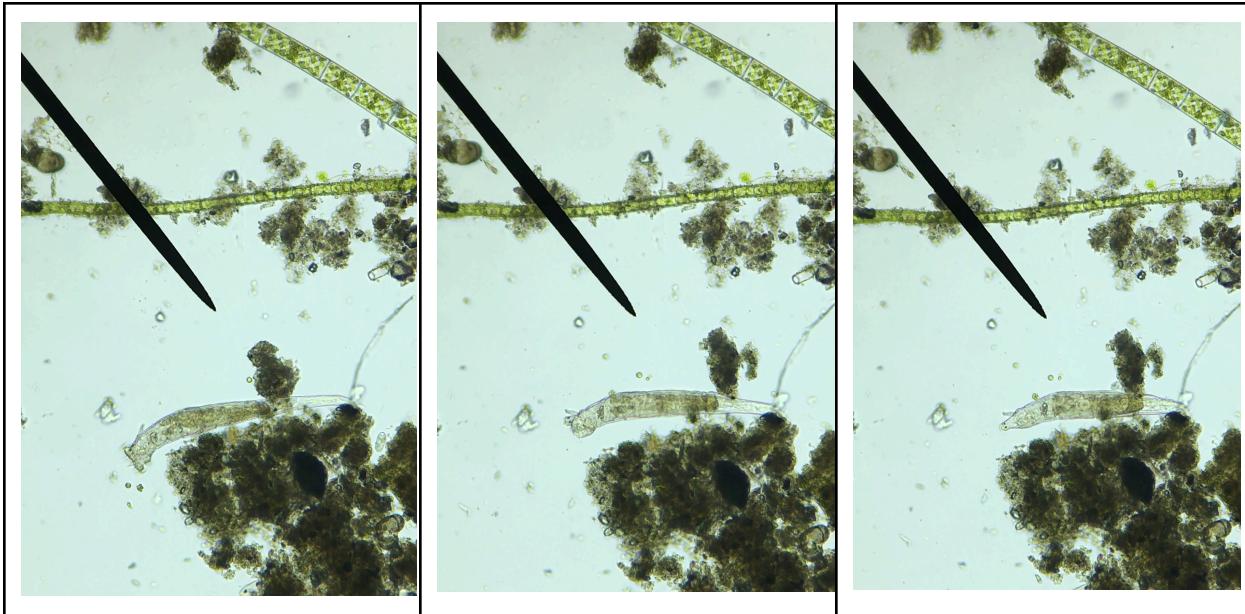
Before beginning, a microscope is one of the most important pieces of equipment for collecting the necessary data for studying Rotifer and Protozoan. The microscope allows humans to see the microscopic organisms that exist; the scope uses lenses, which enhance the magnification, allowing the microscopic organisms to become visible to the human eye. When collecting Rotifer and Protozoa for my research project, I collected them from a freshwater retention pond in my neighborhood, allowing me to easily collect samples as needed. Then, I stored the samples in collection jars for later use. When collecting the samples of these different organisms, I also collected substantial organic material with the water samples to ensure that the microorganisms had a much-needed food supply over the coming weeks of collecting videos and images needed for the dataset when creating the models. The collection of videos and images of the different live Rotifer and Protozoa are all labeled with the proper name of the organism, along with whatever action that particular organism was doing in the slide.



The first microorganism is a protozoan named the Paramecium. It is a Ciliate microorganism that looks like algae and has cilia (small hairlike follicles) along the outside of its body, which allow it to eat and swim. It is a filter-feeding Ciliate that eats bacteria and decaying organic materials, such as plants, within the water. It acts as a cleaner, which allows the water to be clean and healthy for all the other invertebrates to use this ecosystem as their home.

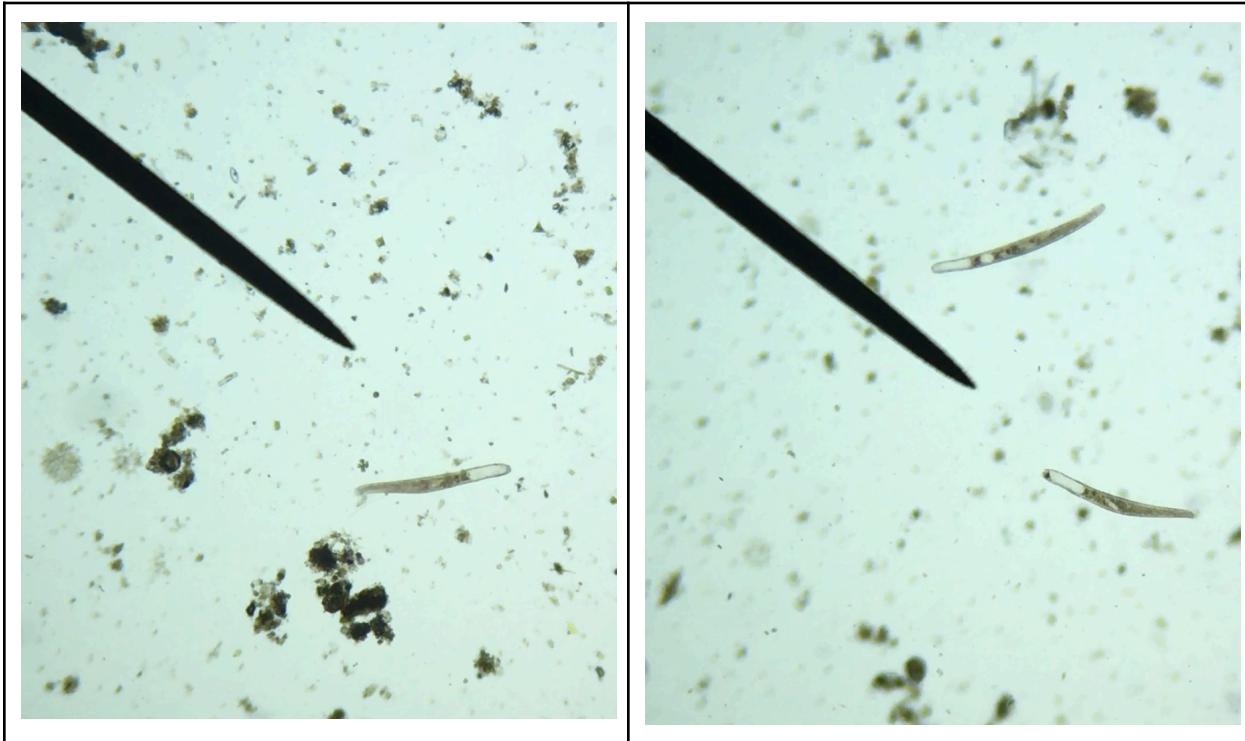


The second microorganism is a small, unidentified Protozoa. I don't know exactly what this organism is, but it is incredibly fast and eats organic material within the samples. It is often seen individually and in clusters with other small, unidentified protozoa of the same type. I included this small unidentified microorganism because it shows how many different microorganisms exist, and I do not have all the answers to identify them. I've done countless amounts of research to identify it, but I have come up empty. I have labeled the microorganism as Protozoa, which allows me to have a collection of small protozoa that have yet to be identified.

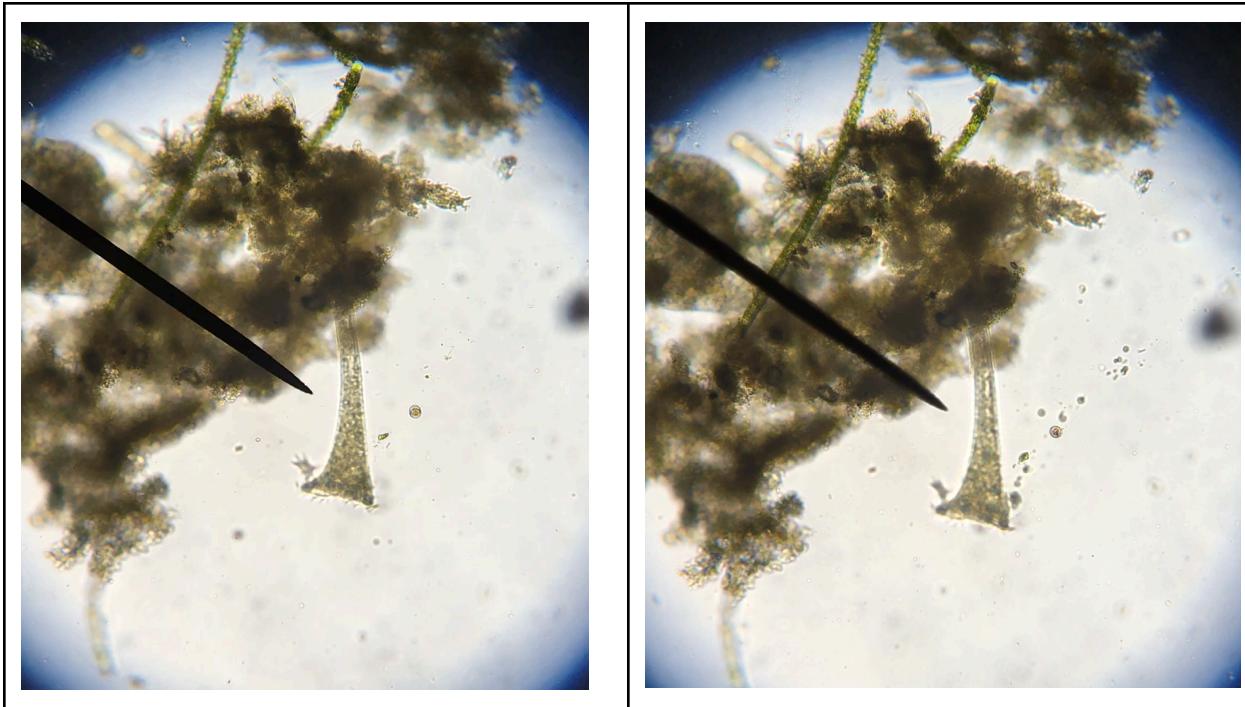


The third microorganism is the Rotifer. The Rotifer is not a Protozoa, which I have recently learned, and I had it confused with Protozoa. The Rotifer is a microscopic animal that looks like a worm based on its structure but acts like a Protozoa. The Rotifer eats bacteria and decaying organic matter but does not have the cellular structure that protozoa have. The Rotifer is a complex microorganism that has large retractable wheel-like jaws that allow it to suck in and capture food with the range of cilia around each jaw that allows the collection of food to pass into its gut. Rotifers, just like protozoa, are extremely important to a freshwater ecosystem. They provide the

nutrients needed for the ecosystem and are a great food scourge for larger plankton and small fish.



The fourth microorganism is a Protozoa named Spirostomum. It is a large Ciliate microorganism that moves incredibly fast and has a long, narrow, cylindrical shape with a somewhat flattened body that eats bacteria and moves around, using cilia (small hairlike follicles) along the outside of its body. The Spirostomum looks like algae and has the ability to contract its body to a quarter inch in length quickly. It is a common freshwater microorganism that looks like a strand of spaghetti under the microscope. The Spirostomum can also expel water through its rear through a long vesicle.



The fifth microorganism is a Protozoa named Stentor. It is a trumpet cone-shaped Ciliate protozoa with a large opening at the top and a slender body that narrows towards the rear. The Stentor is a filtering microorganism with cilia around the large opening, allowing it to trap bacteria and other organic material to eat. Unlike the previous microorganisms, this protozoa can attach and release itself to different organic materials as a base, such as a plant stem, allowing it to be stationary when filter-feeding. The Stentor's role is to clean the water and release nutrients, which helps the freshwater ecosystem flourish.



The final microorganism is a common Protozoa named Vorticella. It is a Ciliate that filters feed similarly to Stentor but has a smaller body. The Vorticella has an inverted bell-shaped body; at the top is the large bell-shaped head that allows food to be eaten using an upper band of cilia that collects the food into the microorganism's body and creates currents in the water for feeding. Towards the bottom of the protozoa, it has a small string-like stem that can attach and release itself to different organic materials, such as plants, similar to a Stentor. The stem of the Vorticella is often longer than its top, which leaves it vulnerable to predators but allows it to stay stationary and move in different directions, increasing its bacteria-filtering food intake, along with other decaying organic material. The Vorticella filter feeds and then releases critical nutrients into the water, allowing the ecosystem to flourish like a Stentor protozoa.

Then, when done collecting videos and images of the microorganisms, I used Roboflow to create the different datasets for both the Object Detection Yolov8 (You Only Look Once Version 8) and Image Classification models. Roboflow is a free and easy-to-use software that allows me to convert the images of microorganisms into object detection and image classification dataset formats, allowing me to train with these models. For object detection, I used multiple labeling and manually highlighted the particular organisms, identifying each microorganism in the photo, which I used to train the object detection model. Then, image classification was very similar, but instead of identifying multi-label images, I focused on single labels, which allowed me to identify one microorganism per image—instead of highlighting and identifying the specific microorganism. I can look at the image as a whole to determine the particular microorganism. One of the big reasons I chose to use Yolo instead of other object detection models is because it has great speed and accuracy for identifying different objects and is packaged with Ultralytics. This open-source package has great documentation and many resources that I use to learn how to use Yolov8 for the model more easily. Then, I used Tensorflow to create the Image Classification model because I was familiar with it, and it was a great way to use deep learning knowledge in the project.

Object Detection and Image Classification are Computer Vision methods that allow the user to understand a particular image. Object detection is a process of identifying the objects and their location within a specific image. The object detection model's dataset includes the photos themselves and returns coordinates on where that specific object is within that image so that the model can be trained to recognize these different objects. The object detection model can identify multiple objects within the same image and video. Then, image classification is the process in which an image is classified based on the entire image. Many different labels can be used, including single and multi-labeled classification. For my project, I used single-label classification, which specifies that only one single label can be used per image. For example, if I have an image classified as a microorganism Rotifer. The image classification cannot be another microorganism. Image classification is less complex than object detection.

Then, when I finished the training on object detection and image classification initial models, I sought to improve the overall efficiency of the model, so I included augmented data. The augmented data images allowed images to be added to the existing microorganism images in the dataset. The different images have related conditions, which improve the model's overall efficiency. For the augmented data images, some of the properties included changing the pixelation, brightness, and zooming in on the particular microorganism to help the computer understand what the particular

microorganism was from the collected data of rotifer and protozoa images. The additional step of creating augmented images helped improve the overall model.

In conclusion, this research project taught me a lot about computer vision and microbiology. My ultimate goal of combining my interests in microbiology and computer vision was achieved in the research that I completed. My biggest takeaway from the project is that I better understand object detection and how it can be used to identify different objects within an image. Then, with image classification, I already had a good understanding of what image classification was, but I now have a more complete understanding of how different images can be classified. Another one of my biggest accomplishments is understanding how to format the images and videos I've collected of the microorganisms and convert them into the right data format so I could train each of these models with a great dataset. The initial process of preparing the datasets is big thanks to the Roboflow software. Finally, in the area of microbiology, in classifying and labeling the different microorganisms, I learned that rotifers are not protozoa. I was always under the assumption that they were protozoa, but I was wrong. They are complex multicellular organisms that do not meet the structural requirements for identifying with Protozoa. They are more complex than protozoa but perform the same function as Protozoa. Overall, the research project was a lot of work, but I found great resources that helped me complete the project this summer, 2024.

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