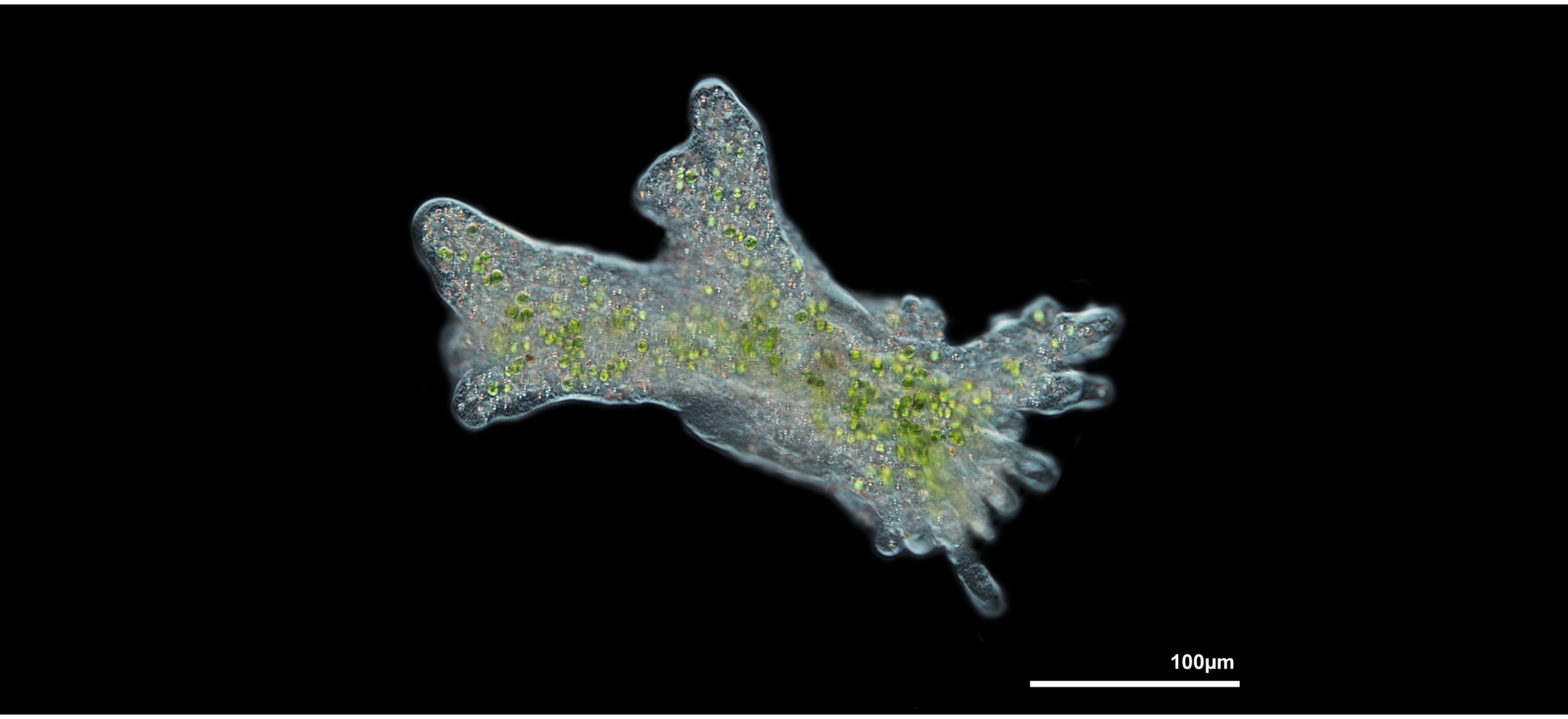
Application note

Microscopy for practical training in zoology



Seeing beyond

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Practical zoological training focuses on the anatomical structure of animals and the unique characteristics of various animal groups. For many students, introductory practical training is the first time they come into contact with zoological objects and acquire knowledge about animal morphology by preparing slides on their own. Following this, cells and structures are examined under the microscope and students discuss what they have observed as a group. Direct experience with specimens is important in helping students better understand the basic structure and the evolution of various organisms, as well as in imparting an awareness of the importance of handling living creatures carefully when conducting research.

The importance of comparative zoology

Excursions, lectures, and hands-on exercises in zoology are integral parts of the study of biology and related fields. Zoology is the scientific study of the anatomy, species history and development (phylogeny), and evolution of individual physiological features (such as the digestive system) of animals. Through direct comparison, the morphological distinctions between various animal groups – for example, insects and arachnids – become clear. Knowledge of such distinctions aids in the taxonomic determination and phylogenetic classification of individual animal groups. The structure of organs as well as of digestive and circulatory systems will vary depending on a species' habitat, life-form, and phylogeny. Whether an animal breathes using gills, spiracles, or any other number of possibilities is determined by the diverse and branching path of its evolutionary history.

Slide preparation and staining, safe handling of microscopes, and making detailed microscope drawings are all important skills to be learned during practical training for zoology. In order to make structures and their composition visible in detail, selected specimens are examined under a microscope after being prepared and stained. Thinly sliced cross sections or squash preparations are visualized using upright microscopes, while in-situ and habitus views of insects, arachnids, mollusks, echinoderms, and smaller mammals are examined under a stereo microscope.

Detailed observations with microscopy

Since students often arrive with varying degrees of prior knowledge, and it is often a long time since some of them have used a microscope, all students receive an introduction to the structure and operation of the microscopes used at the start of the practical training. Students often use both fixed Köhler devices with up to 40× objectives and stereo microscopes.

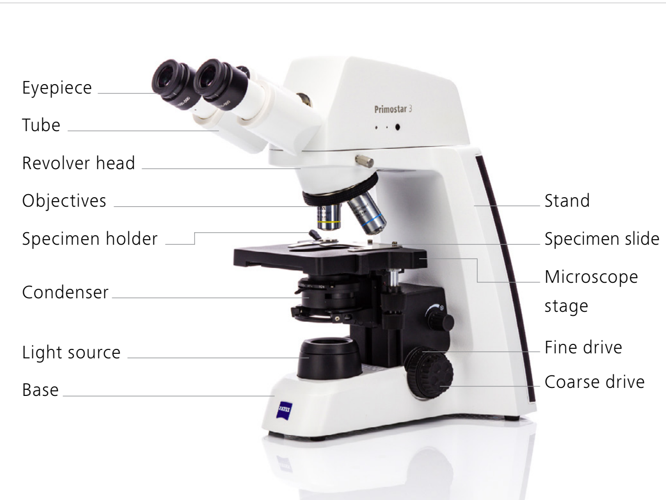

Figure 1 *Structure of an upright microscope.*

Figure 2 *Structure of a stereo microscope.*

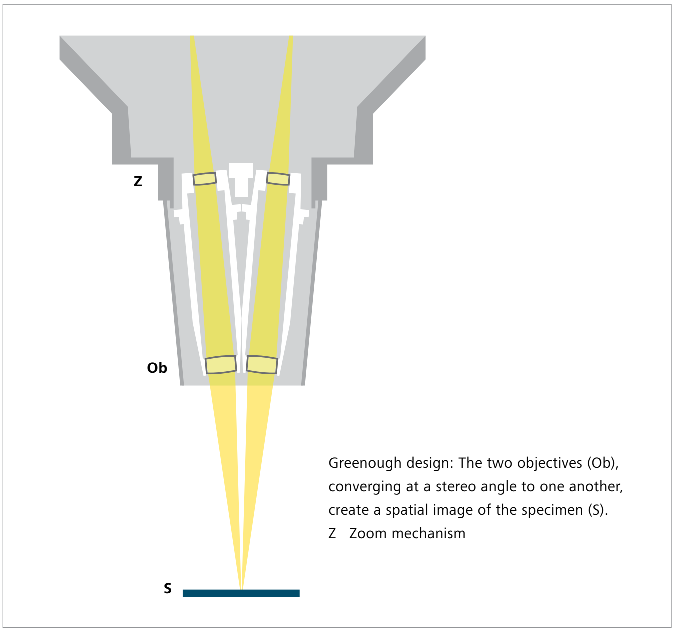

Figure 3 *Stereo microscopes, also called binocular microscopes, consist of two objectives and eyepieces that allow the user to view the object from two sides. This produces a three-dimensional visualization of the specimen.*

Additionally, students learn how to make drawings of the specimens they are viewing through the microscope. Even in the digital age, making drawings of specimens under the microscope is crucial, and such drawings are still an integral feature of scientific publications.

While photographs can be helpful for later work, drawing by hand requires the observer to work closely with the specimen. Making a detailed hand drawing requires precise observation of the specimen:

- Where exactly is the cell nucleus located?
- Where are the contours of the cell membrane?
- What types of cells can be identified?

Hand drawings also act as a record containing information on the researcher, the specimen, and its systematic specification as well as information on the structure depicted, what staining method was used, and the magnification. This record can be used to replicate the experiment.

Figure 4 *Creating microscope drawings serves the joint purpose of documentation and the better understanding of the microscopic image.*

Zoological specimens in detail:
From single-cell to multicellular organisms

Amoebas

Practical zoological training generally kicks off with the study of protozoans, which are single-cell organisms. Protozoans are characterized by the presence of a real cell nucleus. Microscopes can be used to observe living amoebas, for instance.

Amoebas, such as the *Amoeba proteus* observed by students during their training, are single-cell life forms. All the bodily functions for which metazoans have specialized multicellular organ systems have to be managed by this single cell. This is a remarkable feat. Amoebas do not have a fixed body shape. They constantly alter their form by protruding features known as pseudopods, meaning "false feet".

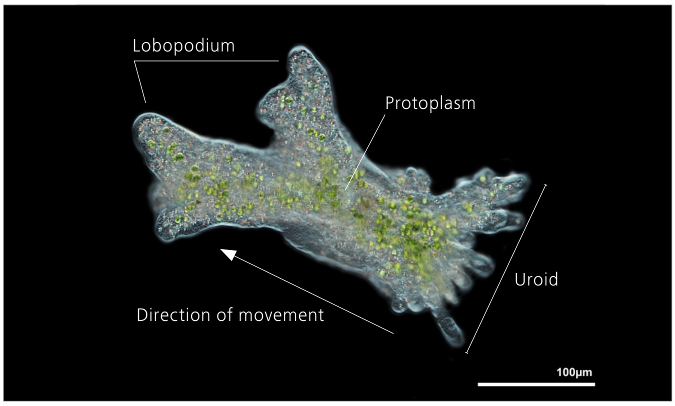

Figure 5 Amoeba proteus *viewed in darkfield mode. Courtesy of St. Clauß, Thum, Germany.*

Under the microscope, one can see that the cytoplasm of *Amoeba proteus* is always in motion. This flow of cytoplasm is especially apparent when a new pseudopod extends. Cytoplasm is present in two conditions: as the outer layer, called ectoplasm, and as endoplasm, the inner area. Ectoplasm has no organelles and has a highly viscous, gel-like consistency due to the large numbers of actin filaments present. Endoplasm, on the other hand, fills a large portion of the cell's interior and has much lower viscosity. An increasing concentration of calcium in one area of the endoplasm activates the enzyme gelsolin. This enzyme severs the actin filaments in the ectoplasm, turning the gel-like ectoplasm into a liquid sol (a process known as gel-sol transition). As a sol, the ectoplasm offers less resistance to pressure from inside the cell, allowing the formation of a small protrusion. More ecto- and endoplasm follow to allow the pseudopod to fully extend. At the edges, the ectoplasm hardens back into a gel-like outer wall. In this way, the amoeba can continuously alter its shape in order to move. During the training, students are able to observe this shifting of shape and the flow of plasma in detail, and will record the motion sequence in a drawing.

Freshwater polyps

The next day of the training focuses on *Hydra vulgaris*, the freshwater polyp. This organism is a member of the Hydrozoa class, a diverse group of cidarians, the majority of which have a polypoid and a medusoid stage in their lifecycles. *Hydra vulgaris*, however, has no medusoid stage and spends its entire life as a free-swimming polyp. The freshwater polyp has a shaft-like body that is oriented downward and a crown formed of 5–12 tentacles. Microscopic cross-section samples of *Hydra vulgaris* are used to illustrate the evolutionary transition from single-cell to multicellular life. Under the microscope, the viewer can clearly see the animal's basic diploblastic structure. This is made up of two layers of cells: the inner endoderm and the outer ectoderm. Additionally, multiple types of cells with varying functions are clearly recognizable. Cnydocites or "stinging cells" help the animal defend itself and catch its prey, while epithelial muscle cells aid in locomotion, sensory cells in perception, and gland cells in the release of digestive enzymes. Functions that take place within one single cell in amoebas are diversified across multiple specialized cells in *Hydra vulgaris*. Live observation of Hydras affords students the opportunity to carefully study and compare their movements. To top off the day, students feed the Hydras and use the stereo microscope to observe how the polyps catch their prey with their tentacles.

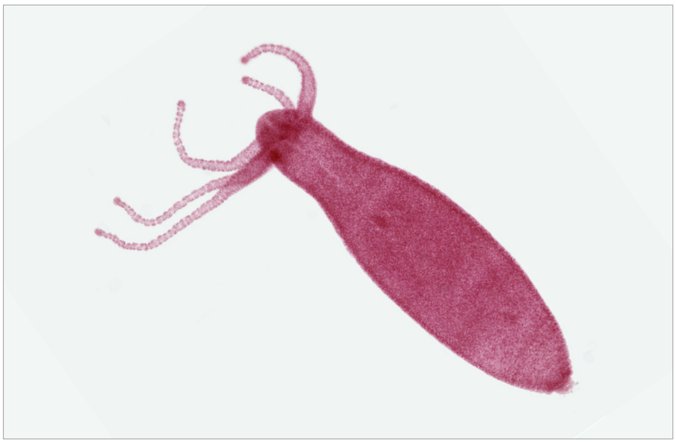

Figure 6 Hydra sp. – *Freshwater polyp. Courtesy of Johannes Lieder GmbH.*

Arthropod appendages

Members of the highly diverse arthropod group have segmented appendages with real joints. The structure of these appendages within various major arthropod groups can vary greatly. Spiders are members of the Chelicerata group.

Figure 7 *Spider leg. Courtesy of Johannes Lieder GmbH.*

Figure 7 shows the typical structure of a spider leg, consisting of the tarsus, metatarsus, tibia, patella, femur, and trochanter.

Figure 8 *Bee leg. Courtesy of Johannes Lieder GmbH.*

The foragial leg of the bee (3rd pair of legs), which is a member of the subphylum Hexapoda ("six legs"), consists only of the tarsus, metatarsus, tibia, femur, and trochanter. There is no patella.

Figure 9 *Bee with pollen on its middle legs.*

The bee's front and middle pair of appendages collect pollen and transfer it to the hairs on the interior surface of the metatarsus. The bee then uses the comb located on the end of the tibia of the opposite leg to brush out the hairs. By doing so, the bee transfers the pollen upward to the pollen basket on the exterior side of the leg. The middle pair of legs is used to press and compact the pollen into the characteristic clumps easily visible to the naked eye. Once the bee has collected enough pollen, it returns to the hive to feed the larvae with its cargo.

The body louse (*Pediculus humanus humanus*) is one of two subspecies of lice that infests humans (*Pediculus humanus*). Body lice live in human body hair and bite their host to feed on their blood. In comparison with other ectoparasites, the body louse exhibits a high degree of adaptation to their host and can only feed on human blood. Body lice use the claw-like end members of their six appendages to crawl from hair to hair on their host. They can barely move on smooth surfaces.

Figure 10 *Body louse* (Pediculus humanus humanus).

Summary

The goal of the training is to impart knowledge of the basic structure of various animal groups by using a selection of species as examples, as well as to give an overview of the most important steps in the evolution of Metazoa.

Detailed observation of zoological samples is made possible by the use of microscopes and stereo microscopes. After an introduction to the structure and operation of microscopes, students study the unique characteristics of various animal groups. A range of didactic methods are employed in order to promote group cooperation and active exchange among students. Group work, keynote lectures, and workshop talks help students dive into the material while promoting group cohesion, ensuring that students actively take part in the training and benefit from interactive discussions.

In addition to professional training, the subject of carefully handling zoological specimens will also be discussed. Models and digital formats are also used to help teach course contents. However, the central focus of the internship is working directly with the once-living specimens. This affords students direct and above all three-dimensional experience with all their senses, leaving a lasting impression. Students are sensitized in a sustainable way to the value of life and to the care that is necessary when researching living organisms. In this way, the zoological intership seeks to strongly oppose the trend that can be observed to date of the increasing distance in research from the object of study itself.

Recommended products

The zoological training is supported by the ZEISS Primostar 3 and ZEISS Stemi 305 educational microscopes. For the Primostar 3 microscope, fixed-Köhler packages (e.g. 415501-0001-000) and packages with an integrated Wi-Fi camera (415501-0071-000) are available to all course participants to allow them to view the microscopic images. Stereo microscopes in the Stemi 305 line offer various configurations and lighting options. The Stemi 305 EDU Set (415501-0011-000) is a complete package with 8× to 40× magnification and integrated LED lighting. The Stemi 305 cam set is equipped with an integrated camera (491903-0005-000).

Figure 11 *Students working with a Stemi 305 cam. The microscopic image is visualized using Labscope on an iPad.*

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