Chapter 1

Biology for the Visually or Orthopedically Impaired

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Introduction

The presence of physically impaired students in biology courses need not create any major problems. Considering the abilities rather than the disabilities of all students results in a positive attitude which is better for coping with individual differences. The first concern should be for providing means for the student to acquire the concepts of the science, rather than to perform techniques unsuited to the handicapped person.

There should be no change in topics for laboratory investigation because of the presence of a physically-impaired person as a member of the class. The mode of communication with a person may vary, but as long as there is some way in which data, observations, and details of every laboratory investigation can be transmitted to the physically impaired, they should be able to draw valid conclusions and assemble the data into a report. No physical disability should exclude a person from the laboratory unless the sole goal of the course is technical performance. Grades in laboratory performance for the severely disabled person should be based on ability to draw valid conclusions and interpret data, rather than on visual acuity with a microscope or performance of techniques requiring visual or manual dexterity.

Before the first lecture and laboratory session the instructor and laboratory assistants should have a conference with the disabled person. The prime question to ask the student is, "How do you plan to manage in this course?" Those who have had previous science courses may have a note-taker, tape recorder, special hearing aids, or other devices needed for acquiring material transmitted via lecture. The student may feel secure in the laboratory and need only to adapt his ways to the new setting and safety regulations. If, however, the person is a novice in science he will need the expertise of instructors and college counselors of the handicapped. In this chapter we shall discuss ways of assisting the visually or orthopedically impaired.

The Visually Impaired

Lecturers aid visually-impaired students and reinforce learning for the sighted if they verbalize as they write or draw on the chalkboard. If, as they draw on the board, they describe a sketch in a standard way it will be easier for the non-sighted to visualize it. Of greater assistance is a packet of raised-line drawings for each lecture to correspond with the material presented on the board or overhead projector. Numerical data, charts, and graphs should be included in braille or large, raised print.

Before assigning a seat to a visually-impaired student, the offer of a seat of choice might be made. Some visually-impaired may prefer a front seat for better reception for the tape recorder. Some legally blind might need a seat where light is optimum. This is a topic for inclusion in the first conference.

A tour of the laboratory before the first session gives the visually-impaired student a chance to locate equipment and materials so easily seen by others. Braille and/or large-print labels should be placed on reagent bottles, shelves and equipment to be used by non-sighted students. The 3M Braille Label Maker simplifies this task. A dial with standard print beneath the braille characters allows the sighted, non-reader of braille to prepare the labels. For visually impaired persons who do not read braille a large, primer print labeler is available to make raised letters on tape.

Alternatives to Microscopy

The question most often raised regarding the presence of non-sighted persons in biology is, "How are they going to manage without using a microscope?" In an average science course among ten legally blind persons only one will be totally blind. Among the other nine who have a small amount of vision, a few will have sufficient sight to use a microscope. Others will require a subdued light and will occasionally be able to use darkfield or phase contrast for viewing. Others may see only with intense light. Some may be able to use a dissecting microscope, and may, in fact, benefit from using it to read printed material. (An inexpensive 8″ × 11″ plastic Fresnel lens on a wooden frame can substitute for this purpose.) An adapter may be used to link a TV camera to the eyepiece of the microscope; this is beneficial not only to those with limited vision, but is also suitable for class demonstrations. If the microscope is considered a means of acquiring data rather than as a goal of the investigation, then the more valid goal may be the ability to interpret data, which might be acquired by auditory or tactile rather than visual means.

Raised-line drawings are a prime technique for giving the totally blind person a sketch of the material normally seen with a microscope. To produce such drawings braille paper or heavy foil is placed on a rubber or plastic mat. The paper is drawn on with tools having various tips which are able to indent, but are not sharp enough to make holes in the paper. A tracing wheel serves to make lines on braille graph paper. Wooden tongue depressors, ball point pens, and nails with rounded tips serve to make lines of different widths. When a course has several visually-impaired and/or learning-disabled students multiple copies of raised-line drawings are necessary. This need may be met by Thermoform duplication. Models for use with this machine are made in the same manner except on flat cardboard and with a heat-resistant glue.

Braille paintings can also take the place of standard prepared microscopic slides. A simplified version of what is seen with the microscope is sketched with pencil on cardboard. The lines are then traced with a liquid glue from a container with a fine nozzle, such as Elmer's Glue. Into this medium string, rope, and wire are added to make lines of varied thicknesses. Buttons, strips of sandpaper, metal chain, small pieces of wood, and other materials are added to represent cellular inclusions. Even a wisp of human hair may represent cilia, and linen thread may become a flagellum. With incentive for competition laboratory assistants can produce four or five of these paintings in an hour when the primary goal is scientific accuracy, not the beauty of the painting. Shallow cardboard boxes are advantageous for long-term, dust-free storage.

When live organisms are being observed microscopically it may be suitable to have the visually-impaired student wander about the laboratory asking fellow students, "What do you find?" The blind student who has a number of pairs of eyes making his observations may well have the best understanding of the topic and the most complete laboratory report of anyone in the class. In courses where this method is not suitable a friend or an aide, at the direction of the blind student, makes observations and performs tasks unsuitable for the non-sighted.

Models are another way to transmit information about organisms traditionally observed with a microscope. Large models from biological supply companies are excellent for use by non-sighted students by tactile means. Protozoa can be realistically modelled from a colloidal substance such as Jello. The Jello may be poured on a cookie sheet and cut to the desired shape after it has set. Or it may be poured into a plastic bag and shaped by ties and clothes pins. It is then placed on a flat pan in a refrigerator to gel. While preparing the Jello, raisins, grapes, peanuts, spaghetti, and other likely items are added to represent cellular inclusions.

Measuring Instruments

The goal of independence in the laboratory requires a few devices and modifications for the visually impaired. If a piece of masking tape is placed at the midpoint of a triple-beam balance a visually-impaired person will be able to feel when the pointer is at the midpoint. It is easy to locate the position of the weights on the beams by touch. The notches on the back beams allow the enumeration of such positions. For the front beam, which is without notches, a braille ruler can be calibrated to the balance so that distance can be converted to weight.

The most readily accessible method for a visually-impaired person to determine the volume of a liquid is to use a plastic syringe. The plunger of the syringe is notched with a sharp instrument to indicate volumes. Alternatively one may construct a liquid-level indicator consisting of an audicator for a sound source, a stainless steel probe, and batteries. When the probe touches a conducting liquid a circuit is completed and a tone is emitted. *Obviously this method is not suitable for flammable liquids such as alcohol and ether.* An earphone makes such instruments more accurate in noisy laboratories. The most important use for this is in locating the meniscus, as in a volumetric flask. This model and a smaller one used for filling coffee cups are made by Science for the Blind Products.

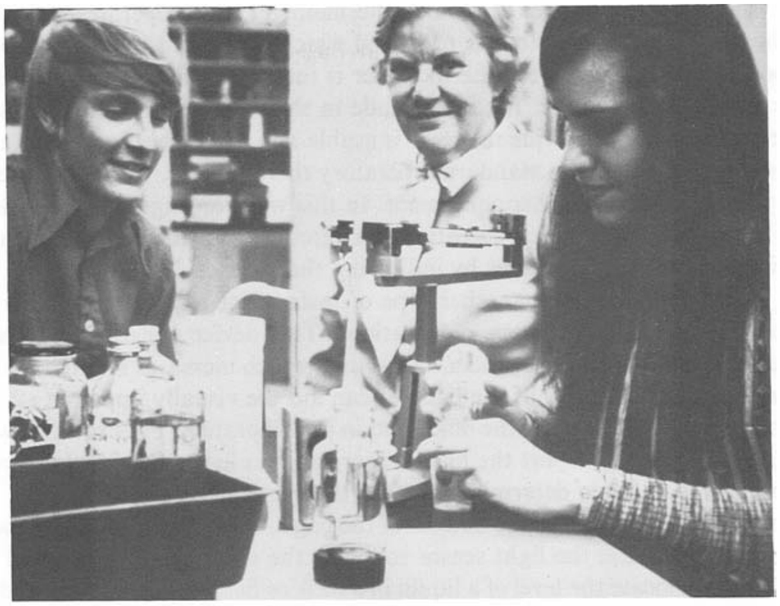


Figure 1.1. Assistant and Dorothy Tombaugh observing a blind student using a balance to assemble an experiment with yeast.

There are several timing devices, from stop watches to large clocks, available with braille numerals. The addition of dots of glue at the lines demarking time on large laboratory clocks serves quickly to turn them into ones suitable for the visually impaired. A talking clock is also now available. In fact, the availability of voice output for instruments is a major item for increasing independence in the laboratory. Any instrument with a digital readout and a BCD (Binary Coded Decimal) output can now be interfaced to a Voice Synthesizer. By this means blind students can now take "readings" on the Mettler Balance, the Sargent-Welch pH meter, the spectrophotometer, digital counters, voltmeters, calculators, computers, and many other instruments. Several instruments may be interfaced to a single Voice Synthesizer.

Another talking device made available since 1980 is ThermoVoice, the talking thermometer from American Foundation from the Blind. It is a laboratory thermometer with a range of −10°C to 110°C when used with the probe in that range. It has another probe in a higher range for use in the laboratory or in a kitchen. Later a probe will be available for use as a clinical thermometer. The unit is contained in a small plastic box which may be worn on a cord about the neck. The stainless steel probes are resistant to most substances. When not in use the probe is stored in a receptacle in the box, which makes it easily accessible for the user. The unit operates on batteries and speaks out, "Low—low" when the batteries need recharging.

The Aud-A-Mometer is a braille thermometer which operates with a null indicator. A continuous tone is produced which is reduced to no sound when a pointer on the face of the thermometer is turned to the value registered by the stainless steel probe. It can be made in short ranges of temperature for accurate work, or in a wide range. It is usable as a soil probe, dark-room thermometer, a clinical or a standard laboratory thermometer. The null indicator may be connected to other equipment. In this way readings can be made by the blind from laboratory potentiometer circuits, impedance bridges, or on resistance-measuring bridges by indicating the absence of the tone.

The Light Sensor is another type of instrument to aid the visually impaired in making laboratory observations. This device consists of a photoelectric cell to detect light, and a tone source which increases in pitch with an increase in the intensity of the light. It can aid the visually impaired student in many ways, at home, in the office and in the laboratory. For example, while typing a laboratory report the light sensor can be used to find the location of print on the page, to determine whether the typed margins are correct, and how close the typing is to the bottom of the page. With a constant light source it is possible to use the light sensor to locate the meniscus in graduated cylinders, or to locate the level of a liquid in a flask or beaker. It may be expedient to mount a fluorescent light fixture with a ground-glass cover vertically to give an even light for making such readings. This may also be an asset for legally-blind persons who have sufficient vision to make certain measurements with standard equipment if the lighting is adequate. Paper chromatograms can also be evaluated by means of a light sensor. Scissors are used to notch the baseline, solvent front, and points at which knowns and unknowns are placed, and the sensor detects the colored spots on the paper.

In tests for various chemicals the light sensor can be used to differentiate between clear and cloudy solutions. It announces the formation of a precipitate by recognizing the change in turbidity or color of a substance. The light sensor will not announce the exact color of the material (yet), but when it is employed repeatedly in similar situations the user frequently comes to recognize different tones as indicating certain colors. In using indicators the light sensor detects a change in color and will detect the endpoint of a titration. Accuracy depends on the individual's hearing, tactile sensitivity, and experience. In the study of water potential of beet tissue and of diffusion through a semi-permeable membrane visually-impaired students have used techniques of weighing, measuring, and preparation of solutions of specific molarity which they learned in previous experiments. The light sensor added the final touch of independence by detecting the red color of the solution as the beet pigment diffused.

Areas of Application: Microbiology

The growth of a microbial culture can be observed using a light sensor to distinguish changes in color and ability of a solution to transmit light. The green alga *Chlorella* is a useful organism for this purpose. Visually-impaired students with good manual dexterity have no problems streaking a culture of algae; the warmth of the gas flame guides them in flaming a needle for sterilization. More precise measurements of growth in cultures in broth can be made with a spectrophotometer connected to a Voice Synthesizer, or one with a special braille dial. The growth of yeast can also be detected by the light sensor or by measuring the volume of CO_2 produced. The quantity of gas produced can be determined by measuring the displacement of water and using the gas laws and the solubility of the gas in water. Evaluating data on growth and metabolism from experiments done by sighted students is another route to the understanding of topics in microbiology by the visually-impaired student. Other routes include the sharing of information from others, raised-line drawings, braille paintings, and models. Larger algae, such as certain fresh or preserved brown or red algae, may also be more suitable.

Botany

The study of plants provides a wide range of topics for research projects and opportunities to learn useful techniques for growing plants in the house or garden. The visually impaired with good tactile sense have as little difficulty in handling fine seeds and transplanting small seedlings as sighted persons. Making cuttings and dipping them into rooting hormone has proved to be an easy task for blind students. For a project on tomatoes and potatoes grafting was done expertly by blind persons. The light sensor was used to detect the presence of indolphenol in determining vitamin C content.

In order to identify plants visually-impaired persons need a new key based more on tactile and olfactory characteristics. With fresh plant material differences in the odor of leaves and stems are as distinctive as is the smell associated with flowers. Using the sense of touch, blind persons often notice details of plant stems and leaves which could be used in plant keys.

For observations in the greenhouse or the garden, the light sensor detects differences in shades of green in leaves, variegation of leaves, and differences in color of flowers. It will give a tone pattern when the petals are variegated, striped, or multicolored. The sense of touch permits recognition of healthy and diseased plants.

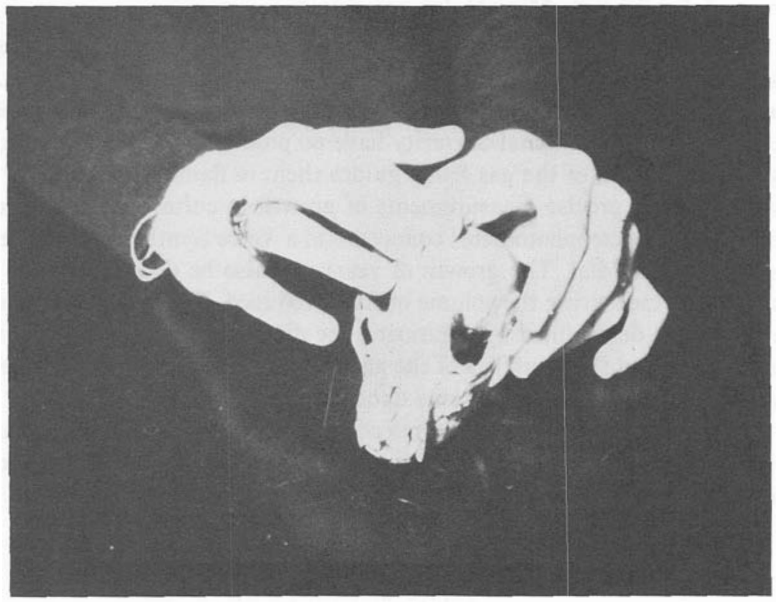


Figure 1.2. A blind student studying anatomy by touch.

Zoology

Details of the anatomy of small animals are best studied by the visually impaired with models, raised-line drawings, books, and verbal descriptions by others. The non-sighted are able to conduct behavior experiments on a number of small organisms such as meal worms, grasshoppers, earthworms, snails, and sow bugs. If large crayfish are to be investigated it is best to immobilize their pincers with rubber bands. Frogs are tethered with a gauze leash to restrain them from exiting the laboratory bench while they are being studied by the non-sighted. The dissection of fetal pigs and large frogs presents no problem for interested visually-impaired persons who have good tactile sense.

For heart rate experiments in which *Daphnia* would be traditionally used, frogs may be substituted to enable the blind students to count the heart beat by touch. Kymographs and EKG tracings may be photographically enlarged and then outlined with the tracing wheel. One blind physician reads his patients' electrocardiogram by means of the Optacon.

For a study of human anatomy the position of muscles can be felt on the student's own body as an aid to learning for the sighted as well as the non-sighted. Large models furnish details of various organs. Details of bone structure are evident to those with good tactile ability. For small holes in bones that might otherwise be missed a fine piece of wire can be inserted and labeled. The dissection of a fetal calf may be a source of additional information for comparative anatomy.

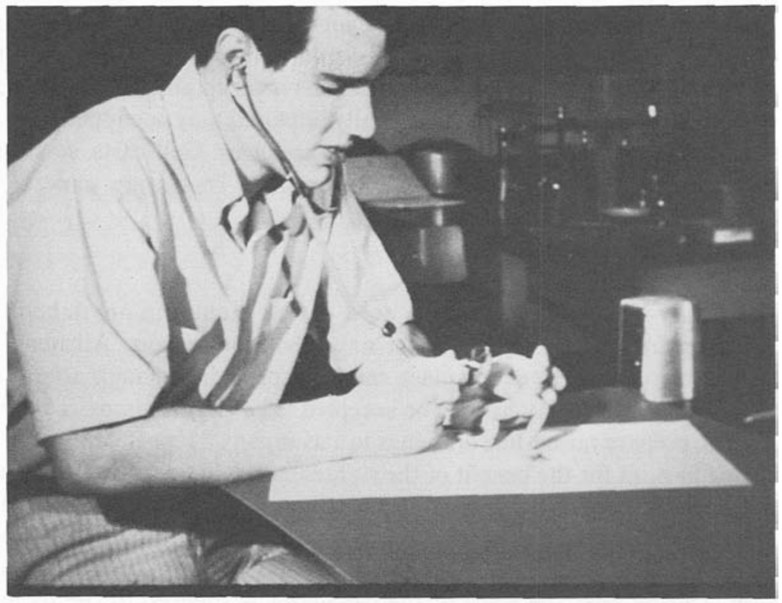


Figure 1.3. The stethoscope permits blind students to study several aspects of heart function in the frog.

Genetics

The concepts of genetics present no more difficulties for the non-sighted than for sighted students. Genetics problems can be calculated mentally or with the aid of a talking calculator. Punnett squares can be modelled as for a braille painting and can be reproduced with the Thermoform machine. For the visually impaired with marginal vision, the raised-line drawings are colored to give an added sensory mode. *Drosophila* cannot be observed readily by the visually impaired or by those with orthopedically impaired hands, but data from experiments done by sighted persons can be used. Investigations using corn, soybeans, and other easily-manipulated materials are better for experiments to be done by those with limited vision or manual dexterity. The difference between green and albino corn may be determined with the light sensor or by variations determinable by tactile means. Yellow and purple colors of corn are identified with the light sensor. Peas and kernels on ears of dried corn are sorted by touch according to wrinkled, shrunken, or smooth characteristics.

Field Studies

By the time they arrive in college some blind students will have had experience in hiking, camping, canoeing, cooking over an open fire, and other outdoor activities used in biology field trips and expeditions. Other students may lack such knowledge, but this should not deter them from such a venture. Any physically-impaired person who will need assistance of any type on a trip should have a fellow student, friend, or aide who is acceptable to the instructor to act as a special guide. (The orthopedically impaired may need special transportation in a wheeled vehicle other than a wheelchair. Golf carts, small garden tractors, wagons, and two-seated balloon-tired Trykes are some of the possibilities.)

Reports and Tests

Physically-handicapped students need not be exempt in any laboratory investigation from any assignments or any laboratory report. All items required of other members of the class can be expected, although alternative modes of presentation may have to be accepted. The visually-impaired can be expected to prepare raised-line drawings to accompany a report. Drawings can be labeled in print for the benefit of the sighted instructor as well as in braille for student reference. Arithmetical calculations necessary for the investigation or the report can often be performed on an abacus. For more advanced computations the Speech-Plus-Calculator or the Canon Voice Calculator is an asset. During tests the voice of the calculator is silenced to the room by means of earphones so that answers are not shared with those nearby.

In most situations it is best to have all students take the same test at the same place and time. Asking students to come for special oral tests is often an imposition on their schedules. For the blind, those with orthopedic disabilities involving head motion and vision, and for certain learning disabilities, putting tests on tape recorders is a good procedure. Some will prefer putting answers on tape as well. With the use of a special face mask or a sound-proof cubicle students can remain in the classroom for testing. Most blind students write script sufficiently well for answers to objective or short-answer questions. A typewriter may be preferred for essays. To have tests brailled may require planning several weeks in advance.

Most of the visually-impaired students who enroll in a beginning college biology course are not planning to be in a related field or to major in biology; however there are a few who may show interest. When we look at the roster of visually-impaired scientists published by the American Association for the Advancement of Science, we find a zoologist who is a college professor, a biochemist, a professor of science education, a physiotherapist, a high-school biology teacher, a physician, a bioengineer, psychologists, a professor of anthropology, a fisheries biologist, a biostatistician, and others. Perhaps there will be a potential biologist who is visually impaired in one of your classes soon.

The Orthopedically Impaired

Orthopedically-impaired persons are well represented in the *Resource Directory of Handicapped Scientists,* published by the A. A. A. S. Biology departments can expect to find enrolled in their courses students with a wide range of inherited and acquired conditions. Some of these impairments are permanent; others due to accidents and athletic injuries may be temporary. Many disabilities are slight and offer little interference with the educational process. Other disabilities are severe enough to require special devices and equipment. Since the disabilities are so varied in their effect there is a limited number of generalities one can make. It must first be remembered that it is the ability of the mental faculties, rather than the disabilities of the physical being, that are the determinants of understanding in science.

As with the visually-impaired student, the orthopedically disabled should have a conference with instructors and laboratory aides to discuss not only the means planned for managing in the course, but more specifically, "What devices do you need to assist your work, and are our laboratory benches at a convenient level for you?" At the college level the student is expected to bear a large portion of the responsibility for participation in lecture and laboratory to the fullest extent allowed by the disability.

Students in wheel chairs may have difficulty maneuvering about some science laboratories. The width of certain aisles is sufficient to turn the chair around, but with a class in the room movement may often be difficult. In other aisles there may be insufficient space to make a complete turn with the wheel chair. The average wheel chair is two feet wide and four to four and one-half feet long, including toe space. From this a student of average height is able to reach half way across a 36-inch high work bench, but this is an awkward and tiring position in which to work. It is also difficult and fatiguing to stand on crutches for long periods, particularly for those unaccustomed to doing so. Carrying chemicals while on crutches is also a potential hazard, not only to the impaired student, but also to others.

Among the solutions for working at a 36″-high laboratory table in a seated position is a movable chair which can be elevated to the desired position (Brindle 1981). A platform with a ramp on which to locate a wheel chair is another answer. Fixtures are provided to clamp the wheel chair securely in place so that it does not move while in use. This platform does, however, impair mobility about the room (Moore 1981). One of the most satisfactory answers was devised by Dr. Robert Larsen in order to move about a college chemistry laboratory in narrow aisles. He nailed an oak desk-chair securely to a 20″ × 24″ wooden platform on sturdy casters. An oak laboratory stool was nailed to another platform to give a variation in height at which to work. The platform chair occupies less than half the floor space required by a wheel chair. It also provides space under the chair for carrying chemicals and other items from the supply area to the laboratory bench. (Blumenkopf, Larsen and Swanson 1981; Coons and Milner 1978.)

One of us (R. T.) has modified the platform chair with metal brackets and wing nuts to allow for assembly and disassembly in a matter of minutes. This arrangement is sturdy, and there is little possibility of the chair collapsing while in normal use. Stability is further assured by locating the large casters near the edges of the corners. Yet the platform is easily stored in a narrow space in a biology office or stockroom, making it quickly available for a temporarily-handicapped person. The platform chair allows one of average size to reach across the 30″ to 36″-high work bench, and it is as usable in the greenhouse and stockroom as it is in the laboratory.

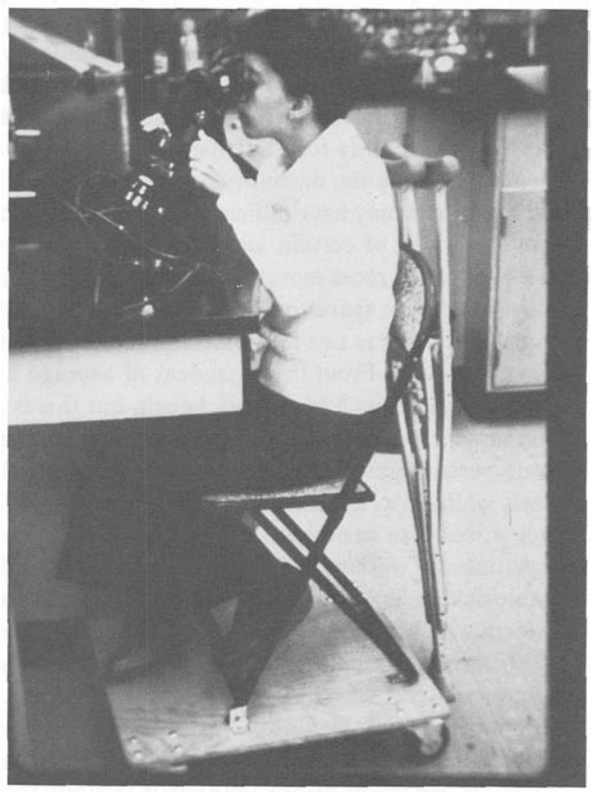


Figure 1.4. The platform chair allows the handicapped student to be seated while working at a standard laboratory bench.

Most people in wheel chairs will need only minor accommodations to work in a biology laboratory with 30″-high counter tops and work tables. A portion of the apron of the table may have to be removed to allow the arms of the wheel chair to fit beneath, and benches with cabinets beneath may have to be replaced by a counter top alone. With consideration for the range in size of people, it may be advantageous to have a counter top which can be raised or lowered to accommodate the needs of each person.

A person with extremely short arms may need a whole face shield instead of just safety goggles, as his face may be brought very close to a working area. Those who are too short to work easily at standard-height laboratory benches may need a platform on which to stand.

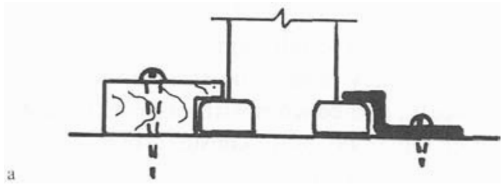
Students with only one arm may need clip boards for holding writing materials and a variety of clamping devices to hold objects during dissection and other laboratory procedures. Unless the impairment is recent the person will have had enough experience to have found techniques transferable to laboratory situations.

The microscope is an important tool for many activities in biology, and the comfort and ease of its use should be considered not only for the physically impaired, but for all students. For some palsied persons a means for securing the microscope to the table should be considered. A wooden or metal frame into which the microscope fits may be fastened to the table temporarily or permanently. If screws can be put into the table top, simple offset bar-clamps of wood or metal can be used (Fig. 1.5a). If the table top cannot be altered the microscope base can be placed in a frame which hooks over the edges of the table (Fig. 1.5b). Students with impaired hands may need an enlarged fine and coarse adjustment on the microscope. It may be helpful to add bars on the knobs, which should turn with a minimum of effort, possibly with a mouth-held probe.

Some palsied people may have uncertain head motions. To prevent injury to the face and eyes while using the microscope a guard may be placed on the oculars. Small, inexpensive rubber shields such as photographers use to keep out stray light will serve such a purpose.

The weight buret which was devised for titration accuracy is suitable for those with orthopedically impaired hands and for those to whom reading a buret in a seated position is difficult, as well as for the blind. A plastic wash bottle is converted into a weight buret by adding a fine tip to assure a small drop. The amount of titrating solution can be determined by weighing.

Easy Grip Scissors are an aid for impaired hands which have difficulty in opening scissors. The handle of the scissors incorporates a plastic strip which acts as a spring: upon release of the handle the scissors will automatically open in the same manner as do pruning shears. Spring-loaded dissecting scissors are also available.



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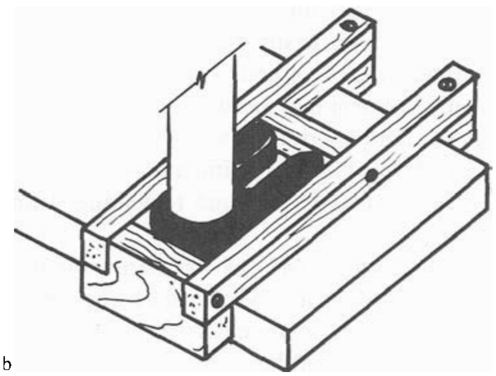

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Figure 1.5. Two types of microscope braces devised by Roy Tombaugh. (a) Wooden or metal offset bar clamps which screw into the table top. (b) A wooden frame which hooks over the table top to prevent lateral movement of the microscope.

People who lack arms or fingers find many tasks in biology difficult. They may need assistance in the laboratory and in note-taking. Tapes of whole lecture sessions often contain extraneous material and need to be edited. Sets of notes from one or more fellow students may be more useful.

As with all disabilities, expect the person to participate in every investigation. Give the student the opportunity to offer solutions to his own problems. When a ready answer is lacking, then as scientists we should draw upon every manner of creativity before resorting to "Just listen and watch."

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Sources of Information and Supplies

Catalog of Recorded Books

Recordings for the Blind, Inc.
215 East 58th St.
New York NY 10022

Fresnel Magnifying Lens

Edmund Scientific Co.
300 Edscorp Bldg.
Barrington NJ 08007

Plastic Magnifier

Chadwick Miller, Inc.
Canton MA 02021

Three-wheeled Vehicle

Carl Heald, Inc.
P.O. Box 1148
Benton Harbor MI 49022

Inexpensive TTY

Automated Data Systems, Inc.
P.O. Box 4062
Madison WI 53711

High-Temperature Glue

Independent Living Aids
11 Commercial Court
Plain View NJ 11803

Visual Aids for Part-Sighted

Visual Tek
1610 26th St.
Santa Monica CA 90404

Pelco Industries, Inc.
351 E. Alondra Blvd.
Gardena CA 90248

Scissors for Palsied Hands

Developmental Learning Material
7440 Natchez Ave.
Niles IL 60648

Voice Synthesizer and Optacon

Telesensory Systems, Inc.
3408 Hillview Ave.
Palo Alto CA 94304

Talking Thermometer
Many other instruments

American Foundation for the Blind
15 West 16th St.
New York NY 10011

Braille Thermometer, Light Sensor, Liquid Level Indicator, etc.

Science for the Blind Products
Box 385
Wayne PA 19807

Thermoform Machine

Thermofax Corp.
Slausen Ave.
Los Angeles CA

Light Probe

San Francisco Lighthouse for the Blind, Inc.
745 Buchanan St.
San Francisco CA 94102

Portable Lab Station

Conoco Industries
30 Water St.
West Haven CT 06516