CHAPTER THIRTY-FIVE

GENERAL LABORATORY SAFETY

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Several agencies are responsible for the occupational safety and health of the American worker. At the federal level, the primary agency is the Occupational Safety and Health Administration (OSHA). This agency develops guidelines and standards covering millions of workers. In addition, each state can develop regulations for occupational health and safety within its borders. There are currently 25 such state plans: 23 cover both private and public sectors and two cover the public sector only. These state regulations must be at least as effective as the federal program. To learn more about the mission and responsibilities of OSHA consult All About OSHA (OSHA 1995a).

Your institutional safety officer should be consulted for guidance when considering specific laboratory safety procedures or designs. This chapter will outline a variety of safety considerations based on OSHA standards as well as other nationally recognized agencies to which federal and state codes look for advice, guidance, and recommendations. These agencies and codes include:

- the American National Standards Institute (ANSI);
- the American Society for Testing Materials (ASTM);
- the National Electrical Code (NEC);
- the National Fire Protection Association (NFPA);
- the National Institute of Occupational Safety and Health (NIOSH);
- the National Safety Council (NSC); and
- Underwriters Laboratories, Inc. (UL).

Other sources that advise OSHA can be found by year in the Federal Register—OSHA. We will also make specific recommendations to guide principal investigators and laboratory personnel, with specific attention given to the psychophysiological laboratory.

The Development of Safety Concepts

Hammer (1989) argued that the development of effective guidelines, laws, and regulations has been based on two opposing ideas: the cost associated with accident prevention and our moral responsibility for the protection and health of human life. Previously, because of the large loss of human life and great number of accidents, pressure came from a number of sources for effective laws, regulations, and development of agencies to reduce accidents and protect the worker and the public. Slowly, adjustments and compromises yielded current guidelines and recommendations.

Another force that led to contemporary concern for safety was the changing nature of hazards and the public's knowledge and sophistication. Hollister and Trout (1979) commented that hazards in the nineteenth century were more easily recognized and simple in nature; today's hazards are more complex and not as easily recognized. Whereas accidents might previously have been limited to particular individuals or groups of workers, today's accidents may be difficult to control and can affect a large number of individuals. Sobering examples are not hard to find: in the Bhopal (India) disaster of December 1984, at least 3,500 deaths and 200,000 injuries occurred from the leak of methyl isocyanate gas (Andress 1996); the Chernobyl nuclear reactor explosion of 1986 in Northern Central Ukraine killed 31 people (according to Soviet statements) and forced more than 100,000 people to evacuate (Norton et al. 1994). Previously, 1979 witnessed the nuclear power plant accident at Three Mile Island, Pennsylvania: meltdown of the core reactor in unit 2 was 52% complete before emergency measures were able to halt the reaction. This accident resulted in the closing of seven similar plants. Couple these facts with widespread media coverage, insurance claims, and advocacy groups and it is not difficult to understand the concern expressed by federal and state legislatures in improving safety. However, implementing new legislation means new costs to businesses, corporations, and institutions of all sizes, whose resistance to change is understandable.

A perhaps more germane example involved Dartmouth College. A chemistry professor spilled "a couple of drops"
permanently installed (OSHA 1996). Otherwise, open switches and unplug the apparatus.

8. Extension cords must have a grounding conductor (OSHA 1996). Inspect the grounding conductor before each use.

9. Exposed wiring and cords that are frayed or have deteriorated insulation are to be replaced immediately (OSHA 1996).

10. Flexible cords should be free of splices (OSHA 1996).


12. Do not use metal measuring tapes (or measuring tapes with metallic thread woven into them) if there is any possibility of contact with energized equipment (OSHA 1996).

13. Before drilling through floors or walls, determine the location of electrical power lines (OSHA 1996).


15. Ground all interior metal electrical raceways and enclosures (OSHA 1996).

16. All energized parts of electrical circuits and equipment must be guarded against accidental contact by approved cabinets and enclosures (OSHA 1996).

17. Mask unused openings of electrical enclosures with appropriate covers, plugs, or plates (OSHA 1996).

18. Remove all metal jewelry before working on or around energized equipment (OSHA 1996).

19. Observe proper voltages and polarities when installing or charging batteries (OSHA 1996).

20. Turn equipment off before unplugging.

21. Have operating manuals of all equipment available. Laboratory personnel should be familiar with the manual and the apparatus (Moak 1994).

22. Label each piece of equipment with its current requirements so as not to overheat the circuit supplying the equipment (Moak 1994).

23. Do not use "cheater" plugs to bypass the grounding probe on the apparatus or extension cord (Moak 1994).

24. Avoid using extension cords for equipment because of the possibility of overheating and increased leakage current (Moak 1994).

25. Special care should be taken so that leads attached to a participant do not contact potentially grounded areas: floors, equipment chassis, or other metal (Moak 1994).

26. Leakage current must be 10 µA or less for any equipment in direct contact with the participant (National Electrical Code 1996).

Prevention of Infection

The acquired immunodeficiency syndrome (AIDS) pandemic has brought to the forefront issues of protection against accidental transmission of infectious diseases. The risk of transmission of body-fluid-borne or blood-borne infection during routine EEG recording, for example, is believed to be extremely low and not documented in the literature – except for transmission under special conditions, such as deep electrode placement in patients with Creutzfeldt–Jakob disease (CJD) (Bernoulli et al. 1977). Although the vast majority of psychophysiological evaluations are performed in people who do not suffer from major medical illnesses, infectious diseases most prone to blood-borne transmission (AIDS, CJD, hepatitis) can present with symptoms that frequently go undiagnosed or unrecognized in the early phases of illness.

Since 1988, the Centers for Disease Control (CDC) has published recommendations for prevention of HIV (human immunodeficiency virus, which causes AIDS), hepatitis B, and other blood-borne pathogens in health-care settings. These recommendations urge the adoption of universal blood and body fluid precautions – that is, all probands are considered to be infected with HIV. We have amended and incorporated parts of the CDC guidelines (1987, 1988, 1989) in the following recommendations for prevention of communicable diseases.

DISEASES

Infectious diseases can be transmitted by any of the following routes: air, contact, vehicle (water, food), and vector (e.g., mosquito, flea, tick). The following section deals with the two routes – air and contact transmission – that are factors to consider in the set-up and maintenance of the psychophysiology laboratory.

Airborne Diseases

Airborne diseases may be caused by inadequate cleaning of the laboratory, a defective ventilation system (legionella), and infected technicians or probands (common respiratory viruses, varicella, tuberculosis). Maintenance of the psychophysiology laboratory and the ventilation system falls under general maintenance guidelines for health facilities and will not be discussed here. Likewise, technicians need to follow health screening and procedures as outlined by their employee health guidelines. Additionally, appropriate care must be exercised so that seemingly trivial – but, for immunocompromised patients, life-threatening – infections such as chicken pox, shingles, measles, and influenza are not transmitted to these patients.

Blood-Borne Diseases

Blood-borne diseases are transmitted in the health-care or laboratory setting by transmission of blood-borne organisms from one person to another, typically entering the bloodstream through an open wound or via penetration injury from sharp objects.

AIDS. The AIDS that is caused by the human T-cell lymphotropic virus type III is characterized by severe and eventually lethal suppression of the immune system. This virus
makes patients susceptible to a variety of opportunistic infections and neoplasms involving the central nervous system. The main route of transmission is sexual contact, which is followed in frequency by blood-borne transmission in intravenous drug abusers and patient groups (e.g., hemophiliacs and recipients of blood transfusions or blood products).

Previous studies have shown that health-care workers in frequent contact with AIDS patients and their blood have remained seronegative (Hirsch, Wormser, & Schooley 1985). The risk of transmission of AIDS is very low unless there is direct blood contact – such as occurs with an accidental stick from a needle used in an infected person immediately prior (Wormser, Rabkin, & Joline 1988). Once exposed to air, the AIDS virus is quickly destroyed and can be inactivated by disinfectants such as sodium hypochlorite (household bleach), hydrogen peroxide, and alcohol at concentrations below those recommended for use as disinfectants (Martin, McDougal, & Loskotski 1985; Rutala 1990) or by way of gas, heat, and chemical sterilants (CDC 1987).

Viral Hepatitis. There are several types of viral hepatitis, including the three types most likely to be encountered in the psychophysiology laboratory: A (infectious), B (serum), and C (serum). Hepatitis A is transmitted enterically by way of fecal contamination, whereas hepatitis B and C are typically transmitted by infected blood (e.g., via transfusions, needle sticks, tattooing, or ear piercing) but also by much less apparent means: toothbrushes, razors, baby bottles, and toys. Infection with hepatitis A causes a circumscribed clinical syndrome consisting of general malaise followed by clinical jaundice and subsequent complete recovery, altogether lasting 2–12 weeks. Hepatitis B and C present with a similar syndrome of longer duration in about 75% of cases. The remaining 25% may experience a prolonged phase of illness with eventual complete recovery; however, about 15% of all cases experience either chronic persistent or chronic active hepatitis.

Unlike HIV, viruses that cause viral hepatitis and CJD are resistant to many conventional disinfectants or sterilants and require adherence to strict sterilizing procedures. The hepatitis A virus is inactivated by boiling for 1 min or ultraviolet irradiation. The hepatitis B virus is inactivated by boiling for 1 min, heating at 60°C for 1 hr, steam autoclaving, or a 5% sodium hypochlorite solution (Journal of Clinical Neurophysiology 1994); the hepatitis C virus can probably be inactivated by these same procedures. Scientists are strongly advised to apprise themselves of current state laws and OSHA standards regarding prevention.

Creutzfeldt-Jakob Disease (CJD). This disease is a rare infectious disorder associated with a proteinaceous particle (prion); it occurs in a familial pattern in 10%–15% of cases. It produces a progressive and terminal spongiform encephalopathy. Mode of transmission is not adequately known. However, the virus resists many common techniques of sterilization and disinfection, including boiling, ultraviolet irradiation, and 70% alcohol. The recommended method of sterilization is steam autoclaving at 121°C at 15 psi for at least 1 hr (Brown et al. 1990).

PREVENTION OF BLOOD-BORNE DISEASES

This section discusses guidelines for preventing the transmission of blood-borne diseases that are uniformly (CJD, AIDS) or potentially (hepatitis B and C) lethal.

The major risk of body-fluid disease transmission in psychophysiological research is related to the routine preparation of the subject’s skin or scalp by abrasion with chemical cleansing agents. This practice carries the potential to produce breaks in the skin with resultant leakage of blood or plasma, which can carry the infectious viral agents just described. According to the classification scheme for infection control, objects and instruments are listed as noncritical, semicritical, or critical with respect to their potential for disease transmission (Garner & Rutala 1986; Rutala 1990).

Noncritical Items

Noncritical items are those that contact intact skin and carry the lowest risk of disease transmission. Such items are surface electrodes, stethoscopes, ultrasonic surface probes, tabletops, and floors. Clean such equipment with a low-level disinfectant before use. Common low-level disinfectants include isopropyl alcohol (70%–90%), sodium hypochlorite (100 ppm available chlorine), and phenolic-, iodophor-, or quaternary ammonium germicidal detergent solution (follow the product label for dilution). Because fluid precautions are to be universally applied, as if all probands were potentially infected with HIV (CDC 1987), technicians should wear nonsterile gloves for procedures involving noncritical items. Because electrodes are commonly placed on abraded skin in the psychophysiological laboratory, the electrodes are considered semicritical rather than noncritical items.

Semicritical Items

Semicritical items are those that contact either mucous membranes or skin that has lost its integrity – as frequently occurs with the process of disinfection and placement of EEG, EMG, ECG, and EDR surface electrodes – or when the skin has sustained cuts, scratches, chapping, or any disease. Surface electrodes should be considered semicritical items, which means they must be free of micro-organisms and require high-level disinfection. In addition, materials such as gauze pads and cotton swabs used to abrade skin are considered semicritical items and need to be sterilized before use. Semicritical items need to undergo disinfection by wet pasteurization or chemical germicides aimed at “eliminating many or all pathogenic microorganisms in
inanimate objects, with the exception of bacterial spores” (Rutala 1990, p. 100).

To reduce the risk of disease transmission between tester and proband, technicians should wash their hands before and after the procedure in addition to wearing disposable sterile gloves. Once surface electrodes are removed, they should be discarded or cleaned with soap and water; if so cleaned for re-use then the electrodes should be rinsed thoroughly and disinfected according to standard hospital sterilization procedures (CDC 1987). Disinfection procedures may involve the same agents used for sterilization at much shorter exposure time (typically 10–20 min). Agents for disinfection include steam, gas, dry heat sterilization, and immersion in chemical germicides registered as “sterilants” with the U.S. Environmental Protection Agency. Commonly used disinfectants are solutions of sodium hypochlorite (AAEE 1986) or 2% glutaraldehyde for disinfecting electrodes otherwise corroded by bleach (Putnam, Johnson, & Roth 1992). Up-to-date information about the use of registered sterilants and the prevention of hazardous exposure can be obtained from the National Pesticide Communications Network (1-800-858-7378) and the electrode manufacturer. After disinfection, semicritical items require storage that will prevent microbial contamination.

Critical Items

Critical items are those that enter sterile tissue or the vascular system (Rutala 1990). In the psychophysiology laboratory, critical items include subdermal electrodes, needles, and the lancets used for skin preparation. Critical items must be sterile at the time of use – free of all forms of microbial life (Rutala 1990) – and must be handled with extreme caution. Their use in the psychophysiology laboratory should be avoided unless absolutely necessary. The risk of disease transmission from an accidental stick from a needle just used on an infected patient has been estimated to be between 6% and 30% for hepatitis (CDC 1989) and 0.35% for HIV (Wormser et al. 1988). After use, subdermal electrodes, needles, and lancets should be discarded immediately in a puncture-resistant container. Subdermal electrodes that are not discarded must be sterilized immediately after use; follow the specific instructions of the electrode manufacturer, then store to ensure continued sterility. Sterilization is accomplished by physical or chemical means. Sterilization procedures typically involve one of five methods (Rutala 1990): steam under pressure; ethylene oxide gas; liquid chemicals such as 2% glutaraldehyde-based formulas (at manufacturer’s recommendations); demand release chlorine dioxide (6 hr); and 6% hydrogen peroxide (6 hr).

CONCLUSIONS ON PREVENTION OF INFECTION

Existing disease prevention guidelines demand that universal precautions be used during evaluations and management of all participants. However, considerable latitude exists in interpretation of what constitutes precautions that are necessary to limit the transmission of blood-borne diseases. Medical situations may range from those with low potential for disease transmission (office visits and physical examinations) to those with high potential for disease transmission – for example, vascular or orthopedic surgeries, which can result in large-volume blood loss with the attendant risk for exposure to a blood-borne pathogen. The laboratory researcher needs to keep in mind the degree of potential disease transmission from these medical considerations. Constitutional symptoms of malnourishment, malaise, discoloration of skin, and chronic cough may herald a chronic and potentially infectious disease process.

The risk of body-fluid or blood-borne disease transmission during standard procedures in the psychophysiology laboratory is extremely low. Routine cleaning of the electrophysiology laboratory and apparatus, use of gloves, and reprocessing of electrodes according to recommended disinfection or sterilization procedures will minimize the risk. Standard sterilization and disinfection procedures are adequate for reprocessing equipment contaminated with HIV or the more resistant hepatitis B virus. More stringent procedures are necessary if the proband is known or suspected to suffer from Creutzfeldt–Jakob disease. These recommendations are formulated on the basis of the best information currently available. Specific recommendations will be revised as public health policies undergo reassessment and new electrodes and sterilants become available.

Health and Risk Assessment

Although testing procedures in the psychophysiological laboratory are generally benign, it is incumbent upon investigators to understand the medical history of participants if anything more than minimal stress is involved or if physical or psychological problems would be relevant to the safety of the participant. In ACSM (1995) may be found the components of a medical history, which can serve as a guide in considering assessment. The American College of Sports Medicine may be consulted for further discussion, with the understanding that ACSM is mainly concerned with exercise testing and prescription. We have used some of these components as a guide for compiling a medical history but have altered the content for relevance to psychophysiology.

Physician Diagnosis. If a diagnosis is relevant to the procedures then it should be obtained. The screening questionnaire will alert the investigator to problem areas that may require follow-up. Relevance, of course, depends on the level of stress imposed on the participant and the purpose of the experiment. Conditions such as diabetes, hypertension, cancer, pregnancy, history of heart disease, and many others may be relevant.
Results of a Physical Examination. If necessary, the results of previous physical examinations can be acquired with permission of the participant. Relevant findings might include strokes, fainting, abnormal blood findings, or cardiac abnormalities.

Current and Previous Symptoms. The Health Problems Checklist (Schinka 1989) is a fairly comprehensive self-administered questionnaire that can be followed by an interview to determine the significance of the symptoms reported. For stress-related research, cardiovascular symptoms could be noteworthy – including pain in jaw, chest, neck, or arms – especially if precipitated by stress.

Recent Problems. Again, each of these must be assessed with regard to its relevance and risk in the experiment. Problem areas here may include recent accidents, illnesses, surgeries, or hospitalizations.

Muscle, Joint, Tendon, or Ligament Problems. If the experiment requires ambulation, manipulation, heavy lifting, or rapid movements (as in tracking), then such problems may preclude participation or require some modification of procedures.

Determine Which Medications Are Being Used and Their Effects. Some medications may suppress heart rate or ventricular function (beta blockers). If, for example, the investigator is trying to stress or exercise a participant to a particular heart rate or blood pressure and the medications are limiting the response, then this must be known.

Use of Other Psychoactive or Performance-Altering Substances. Determine the use of tobacco, alcohol, steroids, caffeine, or other nonprescription substances and whether these substances will affect the participant’s safety in the study.

Level of Physical Conditioning. If you are requiring the participant to exercise, you should know the fitness level of your participant to prevent excessive stress.

Genetic Influences. Assess the family history of your participant to help evaluate risk. Such factors in the family as hypertension, cardiac and pulmonary disease, and sudden death should be known.

Table 6 presents the Physical Activity Readiness Questionnaire (PAR-Q; Reading & Shepard 1992), whose original version was used as a screening device for beginning a low to moderate exercise program. The revised version (presented in Table 6) is less likely to produce false positives, especially in older people. It is designed for people between the ages of 15 and 69. A subject who answers Yes to any of the questions should be advised to consult a physician before beginning an exercise program or having a fitness appraisal. A participant who answers No to all questions can become more physically active or undergo a fitness appraisal. This questionnaire can also be found in ACSM (1995), which includes forms that may be copied for use and contain more information for the participant, including informed consent. The PAR-Q may be useful in screening for the psychophysiology laboratory if exercise is involved; it can also serve as an alerting mechanism for potential problems.

We have discussed two screening tests. We now present a list of all screening devices we examined.

1. The revised PAR-Q just discussed (Reading & Shepard 1992).

2. The Health Problems Checklist, discussed previously (Schinka 1989).

3. The Cardiovascular Rehabilitation History Questionnaire (Wilson, Fardy, & Froelicher 1981). Although slanted toward cardiac rehabilitation programs, this questionnaire contains sections on social history, medical history, and cardiovascular risk factors.

4. The Medical History Questionnaire, which is reprinted in Pollock and Wilmore (1990). This questionnaire was designed by the Institute for Aerobics Research in Dallas, Texas. Sections include general information, present history, past history, family medical history, cardiovascular risk factors, a 24-hour history, and special questions for women. Enough information is requested to enable informed decisions regarding health and cardiovascular risk.

**STRESSORS AND RISK FACTORS**

Psychophysicists can use numerous stressors in investigations: noise, electric shock, cold, heat, social challenges.

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<th>Table 6. The Physical Activity Readiness Questionnaire (PAR-Q)</th>
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Note: If you have a temporary illness, such as a common cold, or are not feeling well at this time, then postpone the activity.

intellectual (mental arithmetic, the Stroop test, problem solving), exercise, and public speaking, to name several. Although the stressors have not been ranked regarding their physiological import, at this time an absolute ranking is probably not possible because reactions vary as a function of a participant's history, age, gender, health, and genetic makeup. Nevertheless, the investigator should take into account risk factors and health status before subjecting a participant to high levels of stress, especially exercise. Further guidance to the investigator is available by obtaining information regarding factors that predict cardiovascular (CV) disease. We emphasize CV risk because high levels of stress may precipitate CV incidents. If they choose to process an at-risk subject, laboratory personnel must be capable of recognizing a CV incident or an impending incident and be prepared for correct action. Laboratory personnel must also know when to not include a particular participant in a study, and so a careful evaluation of the medical history is necessary.

Common risk factors for CV disease (and hence for the increased possibility of a CV incident) can be assessed by interview, blood pressure, and serum cholesterol. There are currently no specific guidelines for imposing stressors in the psychophysiology laboratory. In our opinion, data need to be obtained and interpreted to help the psychophysiologist assess the medical implications of stress for laboratory work. Here, at least, we can present the common risk factors that are predictive of CV disease; these factors are especially important for evaluating a participant who is to undergo exercise testing or who is to begin an exercise program. Common risk factors for CV disease that should be assessed include:

1. age — men older than 45 and women older than 55;
2. cigarette smoking;
3. systolic blood pressure measured at rest (greater than 140 mmHg systolic or greater than 90 mmHg diastolic or both);
4. total serum cholesterol greater than 200 mg/dl (note: high-density lipoprotein cholesterol greater than 60 mg/dl is considered a positive risk factor; i.e., it lessens the CV risk);
5. insulin-dependent diabetes mellitus; and
6. a sedentary life style.

A fuller discussion of these risk factors can be found in ACSM (1995) and Gordon and Mitchell (1993).

**SPECIAL CASES AT RISK**

There is a peculiar lack of studies from the psychophysiological laboratory regarding electrocardiographic (ECG) analysis — other than the usual measurement of R-R wave intervals for calculating heart rate and the work of Furedy and his associates (Furedy, Hesegrave, & Scher 1992) on T-wave amplitude changes during stressful tasks. One method the cardiologist uses to help diagnose heart disease entails analysis of the waveforms and intervals of the ECG. Perhaps this paucity of psychophysiological data reflects the lack of interest in these changes as they might reflect psychological processes or, perhaps, the lack of training of investigators in recognizing and evaluating such changes. Electrocardiographic research could provide data for normal subjects and for participants with different degrees of risk (or with disease) at baseline and during various stressful situations.

Studies have reported on diagnosed CV participants who were subjected to psychological stress in order to assess CV function during stress, as indexed (at least partially) by ECG and blood pressure. Our purpose here is not to review that literature but to present a few paradigmatic reports — which will indicate the diagnoses and the CV changes found — to alert the psychophysiological investigator regarding such diagnoses and the CV risk.

Rasmussen and co-workers (1984) used cold pressor (CP) and hyperventilation as stressors on male and female patients admitted for coronary angiography due to attacks of chest pain. An S-T segment elevation or depression (see later section on terminating a session) greater than 0.1 mV or significant T-waves were seen in 25 of 105 patients (23.9%). Coronary angiography indicated that the abnormal ECG changes were due to reduced diameters in the ischemic related vessels. Specchia and colleagues (1984) had 122 patients perform mental arithmetic during coronary arteriography and found significant S-T segment abnormalities in 22 of them. Of these 22 patients, the 20 who were given an exercise stress test all showed S-T segment abnormalities.

In a study using radionuclide ventriculography, Rozanski and associates (1988) used several stressors: mental arithmetic, the Stroop task, simulated public speaking, and reading. The responses were then compared with those induced by exercise for 39 patients with coronary artery disease and 12 control subjects. In the patient group, 23 (59%) had ventricular wall abnormalities while undergoing the mental stressors and 14 (36%) had a statistically significant fall in ejection fraction (the percentage of blood ejected from the heart on a given beat). It is interesting to note that the magnitude of the cardiac abnormality during the personally relevant speaking task was similar to the abnormality caused by exercise and proved to be the most potent mental stressor. Finally, in 19 of the 23 patients (83%) showing abnormal wall motion, no symptoms were experienced (silent ischemia). Regarding safety of the participant, this study shows that processing at-risk subjects who have significant physiological symptoms may not report such symptoms; thus, it seems obvious that ECG monitoring is necessary for persons at high risk or with known disease.

More recently, Legault and colleagues (1995) worked with 46 patients with stable coronary artery disease. They
found that 23 of the patients (50%) showed an ischemic response to mental stress (giving a 3–5-min speech about their own faults or bad habits) as assessed by a decrease of ≥ 5% in left ventricular ejection fraction. When the patients wore Holter monitors during 48 hours of ambulation, the investigators found that mental stress–induced ischemia in the laboratory was significantly associated with ambulatory ischemia, as indicated by S-T segment depression. In other words, ambulatory ischemia was predicted by mental stress–induced ischemia. Again, for participants at risk — in this case, diagnosed coronary artery disease — mental stress produced a potentially dangerous circumstance; without monitoring the S-T segment, depression would have not been detected.

**WHO IS AT RISK?**

It is recommended (ACSM 1995) that laboratory personnel be trained and certified in CPR in all situations where exercise testing is undertaken. We apply this recommendation to the psychophysiological laboratory when any stress testing (psychological or physical) is performed or when any electronic devices are attached to a participant. This recommendation, along with the protocols discussed previously, will make the processing of subjects much safer.

However, the question of risk still remains. Can we safely process any participant? If not, then who is to be excluded? Do we need physician screening for some participants? With regard to exercise, the investigator should consult ACSM (1995); further guidelines may be found in Fletcher et al. (1990). However, if a person has known disease then the principal investigator is responsible for taking acceptable precautions. Should a medical examination be recommended, then discussion with the examining physician is prudent in order to obtain an informed medical opinion regarding whether to proceed with exercise testing. For psychological stress testing, the criterion established for minimal risk by the National Institutes of Health (1993) may be followed:

A risk is minimal where the probability and magnitude of harm or discomfort anticipated in the proposed research are not greater, in and of themselves, than those ordinarily encountered in daily life or during the performance of routine physical or psychological examinations or tests.... For example, the risk of drawing a small amount of blood from a healthy individual for research proposes is no greater than the risk of doing so as part of routine physical examination. (p. G-8)

Using this minimal risk criterion, the investigator can proceed with testing for most participants without physician consultation; additional safety can be added using a medical screen. Stressors are certainly encountered in daily life that are of greater intensity than those usually employed in the psychophysiology laboratory. Even so, if an investigator accepts a participant into a study then responsibility for the well-being of that participant shifts to the investigator. Simple screens and interviews will help to avoid the criticism, “You should have known.” Finally, the research reviewed in the previous section provides further data on reactions to stress for persons with known cardiovascular disease.

**Safety Monitoring of Participants**

We have just discussed risk assessment prior to accepting a participant in a study that involves physical or psychological stress. We now go on to monitoring participants via ECG and blood pressure (BP). If screening has determined that a person has cardiovascular disease or is at high risk, then medical clearance should be obtained and the ECG and BP should be monitored to detect ECG and BP changes which signal that, without medical supervision, a test should be stopped. The full set of criteria for stopping an exercise test can be found in ACSM’s (1995) Table 4-6 for apparently healthy adults and Table 5-4 for clinical testing. We recommend that the full ACSM (1995) guidelines be obtained for laboratory use if exercise is part of your protocol. The monitoring of the ECG requires training and experience. Several references can be consulted to begin learning about ECG monitoring (ACSM 1995; Durstine et al. 1993; Froelicher 1987; Goldberger & Goldberger 1994; Scheidt 1986). The American College of Sports Medicine provides training, certification programs, and testing for different levels of skill and knowledge for those interested (ACSM 1995). In the next sections we will give some common-sense and technical criteria for terminating a session.

**TERMINATING A SESSION**

If the investigator — after screening the participant — has decided to proceed, then special criteria can be used that will help determine when a session should be ended. These criteria include real-time observation of the subject as well as the subject’s ECG and BP. The criteria given here are not exhaustive (see ACSM 1995) but are listed so that investigators and laboratory personnel may, without extensive training, make informed decisions (see also Figures 3–6). The following events constitute criteria for termination of an exercise session (see the next section for details):

1. the S-T segment shows a downsloping, horizontal, or upsloping depression > 2.0 mm from a baseline determination;
2. the S-T segment is upsloping from the baseline > 2.0 mm;
3. ventricular tachycardia is suspected;
4. three or more premature ventricular contractions in 1 min or less;
5. atrial fibrillation or atrial flutter; 
6. elevation of systolic BP > 260 mmHg or diastolic BP > 115 mmHg; 
7. moderate to severe angina; 
8. cold, clammy skin or cyanosis; 
9. mental confusion or dizziness; 
10. verbalizations of distress or discomfort; or 
11. participant requests termination.

Although these criteria are taken from guidelines on exercise, they can also provide guidance for other types of stress testing.

THE ELECTROCARDIOGRAM

The electrocardiogram is measured by affixing electrodes near the heart. There are agreed-on configurations used in clinical work that enable interpretation of the resultant waveforms. Full monitoring is accomplished using a 12-lead system, which electrically views the heart from different perspectives; with the 12-lead system it is more likely that an abnormality can be detected. Determining heart rate and interbeat intervals requires only one lead, so long as some particular aspect of the ECG is reliably obtained. Clinical work requires that the stream of ECG signals be traced on an oscilloscope, computer screen, or other recording media at 25 mm/sec with the amplification set to 1 mV/cm. (Other criteria for recording the ECG can be found in Chapter 9 of this volume.) This section augments the previous section, where test termination criteria were set forth.

Many laboratories do not have the necessary apparatus to record a 12-lead ECG; nor is this necessary for most psychophysiological research purposes. It is possible to use a single-lead system, which can detect S-T segment changes and arrhythmias but is not as sensitive as the 12-lead system. Pollock and Wilmore (1990) discussed the most sensitive of the single, bipolar leads: the manubrium-to-V5 lead, termed the CM1. Using the CM1 with the bipolar attachment (left arm negative and V5 placement positive) and the V1 configuration yields a three-lead system that is quite sensitive to abnormal ECGs; this configuration was made popular by Ellestad (1986). However, if only one lead is to be used then the CM1 is recommended. To obtain the CM1 configuration, place the negative electrode on the manubrium and the positive electrode on V5. To find the V5, place a mark in the fifth intercostal space at the midclavicular line; then place the electrode at the same level as the mark but at the anterior axillary line.

Figure 3 shows three types of S-T segment depressions: upsloping, downsloping, and horizontal. The S-T segment depression can be caused by an ischemic condition in the heart, although other causes are possible (e.g., drug effects, hyperventilation, electrolyte abnormalities). To be significant, the depression must occur 0.08 sec after the end of the QRS waves and be ≥ 1 mm. Downsloping S-T segment depression is considered to be the most specific for ischemia, followed in significance by horizontal and then upsloping forms (Scheidt 1986). The ECG in Figure 3 shows the P wave, the Q wave, the R wave and the S wave. The S wave begins where the downswing of the R wave crosses the “isoelectric” line, which is the level of a line extending from the end of the T wave to the beginning of the next P wave. It can be seen that each of the three insets have greater than 1 mm depression at the 0.08-sec point. The S-T segment change may be accompanied by chest pain or other signs of angina: jaw pain, arm pain (especially left arm), or throat pain. Ischemia is not always accompanied by pain; there can be silent myocardial ischemia. The S-T segment depression does not always accompany ischemia, and the actual depression may be
very subtle. Other ECG abnormalities (e.g., T-wave flattening or inversions) may accompany myocardial ischemia even when S-T segment depression is absent (Goldberger & Goldberger 1994).

Another possibility is S-T segment elevation. Figure 4 shows a 12-lead ECG recording with elevations occurring in all leads except V1. The generalized elevations shown in so many leads are probably diagnostic of pericarditis (Scheidt 1986). However, elevations can result also from cardiac inflammation, strong myocardial ischemia caused by cardiac arterial occlusion or vasospasm (Prinzmetal’s angina), ventricular aneurysm, myocardial infarction, and early repolarization (i.e., the T wave begins during the S-T segment).

Figure 5 shows premature ventricular contractions (PVCs), which can be recognized by three characteristics: (i) they occur before the next normal beat is usually expected; (ii) the QRS complex is abnormally wide (i.e., ≥ 0.12 sec); and (iii) the QRS and the T wave are (usually) of opposite polarity. Several conditions can initiate PVCs, including cardiac stimulating drugs (e.g., caffeine), anxiety, underlying cardiac disease, acute myocardial infarctions, electrolyte disturbances, hypoxemia, and irritable foci in the ventricle itself. Although PVCs are fairly common, even in young healthy people, frequent PVCs can be serious. Ventricular tachycardia is, by definition, a run of three or more successive PVCs. A longer series can lead to hypotension, syncope, or even ventricular fibrillation and death. Should PVCs begin to occur, it is necessary to stop the experiment, relax the participant, monitor the ECG, and prepare for an emergency. Part A of Figure 5 shows three PVCs occurring successively; part B illustrates full ventricular tachycardia. The ECG record shown in part B is life-threatening and so immediate emergency measures would be needed. The sequel can be ventricular fibrillation during which no blood is pumped from the heart; death is imminent without immediate intervention.

The last of the cardiac arrhythmias discussed here are atrial flutter and atrial fibrillation; these two conditions are presented in parts A and B (respectively) of Figure 6. Atrial flutter and fibrillation are the result of a focus or many foci in the atria that stimulate the atria to contract – the stimulus is no longer the standard pacemaker of the heart. Atrial flutter produces a characteristic sawtooth wave call the F wave. Atrial flutter rarely occurs in the normal heart but is found in patients with valvular heart disease, chronic ischemic heart disease, hypertensive heart
disease, and other cardiac myopathies. Paroxysmal atrial flutter may also occur in the healthy heart because of psychological stress or excessive alcohol consumption (Goldberger & Goldberger 1994). The rate of depolarization is quite rapid, about 250–350 beats per minute (bpm). The ventricular rate is usually some fraction of the flutter rate: 1/2, 1/4, or 1/8.

In atrial fibrillation, the heart rate is in the range of 400–600 bpm. The waveform is irregular and wavy instead of the usual P wave. The fibrillatory waves are called f waves. The ventricular rate is quite rapid, but the interbeat interval is very irregular because only some of the f waves are able to stimulate the atrioventricular node. Because the pumping action of the atria is not coordinated, the amount of blood reaching the ventricles is less than normal and so cardiac output is lowered, which can result in hypotension and myocardial ischemia. Obviously, if these conditions develop then testing should be stopped and emergency measures taken.

![Atrial flutter waveform](image)

**Figure 6.** Part A: Atrial flutter with characteristic f waves. Part B: Atrial fibrillation with characteristic f waves. Redrawn with permission from Goldberger & Goldberger, *Clinical Electrocardiography: A Simplified Approach*, 5th ed. Copyright 1994 C. V. Mosby Company.

This brief discussion of the abnormal ECG is very incomplete. However, the conditions presented should allow the investigator to recognize some abnormalities and stop a session. Usually, however, some diagnosis will have been made; again, the importance of health and risk screening is evident, and the laboratory supervisor needs to obtain medical advice before proceeding in some cases. If any of the conditions develop unexpectedly, the session can be stopped. A great deal has been written covering the ECG and how to read and interpret the various waveforms. The interested reader can certainly pursue this area but should receive special training and certification to achieve competency.

**BLOOD PRESSURE MONITORING**

To ensure that blood pressure does not rise to dangerous levels during a procedure, it is necessary to monitor correctly. A procedure described by the American Society of Hypertension (1992) is reprinted as an appendix of the ACSM (1995) *Resource Manual*.

One aspect of monitoring that is not always covered in descriptions of methods is the auscultatory gap. When a cuff is inflated into the range of pressures below the systolic and above the diastolic, one expects to hear Korotkoff sounds. If these sounds are not heard, then the operator assumes that the artery has been occluded and cuff pressure is above systolic pressure. However, this may not
always be the case, since some individuals have a range of pressures between systolic and diastolic where no sounds are heard; this range is called the auscultatory gap. To verify that cuff pressure is above systolic, the radial pulse must be palpated until the inflating cuff pressure stops the pulse. At that point, one can be certain that systolic pressure has been exceeded by the cuff. Then merely continue rapidly inflating the cuff to 30 mmHg above the disappearance of the radial pulse before beginning deflation. Care must be taken when deflating the cuff that, upon entering the auscultatory gap, the operator does not assert that diastolic pressure has been obtained; continue deflating the cuff and the Korotkoff sounds will re-appear.

We have recommended terminating procedures when systolic pressure exceeds 260 mmHg or diastolic pressure exceeds 115 mmHg. Although these values are recommended by ACSM during exercise testing, there are no recommended values for terminating psychological tests; moreover, psychophysicists use exercise as a stressor and for other purposes (Delistraty et al. 1992). Because regulatory mechanisms of blood pressure for psychological stress are different from that of exercise, we can only present the ACSM guidelines and suggest that the investigator consider these as stop-points in stress testing.

However, it is unlikely that stress testing of a psychological nature will drive blood pressures to exercise levels. We searched the journal *Psychophysiology* (1992 through May 1997) to determine the magnitude of blood pressure values reported. The highest values were reported by Sundin et al. (1995). Average systolic BP values of 153 mmHg and diastolic BP values of 106 mmHg were reported for postmyocardial patients on an arithmetic task, and similar values for the cold pressor task were also found. Healthy controls produced an average diastolic BP of 104 mmHg for the cold pressor test and 98 mmHg for mental arithmetic. Although standard deviations and ranges were not reported, we can assume that diastolic BP of 115 mmHg was approached or exceeded in one or both groups by some participants.

**Summary and Recommendations**

Four general nonmandatory principles were established by OSHA (1996) to guide the development and maintenance of an effective safety and health program. When dealing with laboratory safety, these principles can be used as general guidelines:

1. commitment of management and involvement of employees;
2. analysis of the worksite;
3. prevention and control of hazards; and
4. proper training of personnel.

The following discussion is based on these principles.

Principle 1 effectively requires the principal investigator or department head to provide resources and controls in the laboratory with an effective commitment toward the safety of laboratory personnel and participants. Involvement of members of the department and of laboratory personnel in setting up guidelines is essential and promotes their commitment. The means by which this goal may be accomplished should include at least: (a) a stated policy, so that all involved clearly comprehend the importance of the safety and health policy; (b) establishment of clear safety goals; (c) a means of showing that supervisors and the department head are clearly involved; (d) active involvement of laboratory personnel and department members in the development of policies and procedures; (e) designation of specific responsibilities to all those actively involved in the laboratory and department; (f) allocation of adequate authority and resources to those in positions of responsibility; (g) a means of assessing the accountability of those responsible; and (h) a review of the program, at least annually.

Principle 2 requires an examination of the laboratory to identify hazardous or potentially hazardous conditions. The following are recommendations for achieving that goal: (a) conduct a comprehensive survey of the laboratory; (b) analyze any new laboratories, additions to the laboratories, changes in systems, and new equipment; (c) routinely re-evaluate the laboratory; (d) provide a way for laboratory personnel to notify supervisors and department heads regarding hazardous conditions; (e) consider the potential for “near-misses” or other incidents or accidents for effective prevention in the future; and (f) analyze any illnesses or accidents over time to identify patterns for future prevention.

Principle 3 is intended to prevent hazards or, at least, to control hazardous conditions if they cannot be eliminated – as in the presence of blood-borne pathogens. Means towards the realization of this principle include: (a) engineering techniques – for example, use of soundproofing materials to reduce noise; (b) safe laboratory procedures and effective enforcement of such procedures; (c) reducing length of exposure to hazardous conditions; (d) supplying protective equipment; (e) requiring regular maintenance of equipment to prevent malfunction; (f) developing an effective plan for emergencies and periodic practice of the emergency plan; and (g) developing a medical plan that includes CPR, immediate first aid, and a means of mobilizing the nearest physician or emergency medical care.

Principle 4 is concerned with the training of supervisors and laboratory personnel. Laboratory personnel must be made aware of the potential hazards in the laboratory and of effective means of avoiding such hazards. Laboratory supervisors need training to identify and anticipate hazards, and they should reinforce the training of employees regarding hazardous conditions and the need for protective measures.
Blanton (1988) discussed the relationship between safety, OSHA, and the academic laboratory. He found safety considerations to be severely lacking, in part because OSHA has not generally been concerned with academic laboratories but rather with small businesses and industry. However, hazardous conditions do exist in the academic laboratory, as this chapter readily attests. Academic laboratories need special consideration because: (a) students who work in the laboratory are transient and not well-trained in safety principles; (b) the need for training of new laboratory personnel is generally not a high priority; and (c) the allocation of funds and resources for safety compete with funds used for supplies, equipment, and salaries. The protection of all persons involved in laboratory research needs to move to a much higher position in the hierarchy of concerns.

Blanton asked academic institutions how safety could be improved. A number of suggestions were given. First, make OSHA requirements more clear and relevant to the academic environment. (Interestingly, more contact with OSHA was seen as desirable.) Second, periodic inspections by OSHA were seen as welcome. Third, respondents wanted more training of personnel and a stronger commitment by the administration to safety matters. Fourth, Environmental Protection Agency (EPA) qualified personnel were seen as needed to supervise disposal of materials. Fifth, consultants were needed to help with allocation of institutional funds for compliance. Finally, the respondents suggested that – because education is the purpose of academic institutions and since laboratory training is a necessary part of that mission – the community should share more in the financing of safety.

NOTE
The authors wish to thank Ginette Blackhart for bibliographic and figure preparation and Cherie Jackman for bibliographic preparation.

REFERENCES
of dimethyl mercury on her latex glove while working in the laboratory in August 1996. Dimethyl mercury penetrates latex gloves immediately and is then absorbed through the skin. The chemist was hospitalized in January 1997 after tests showed 80 times the lethal dosage of mercury in her blood; she died of the exposure in June 1997. OSHA proposed a fine of $13,500 against Dartmouth for not providing proper training regarding the limitations of safety gloves and for having a deficient chemical hygiene plan for the laboratory (San Diego Union-Tribune 1997).

The history of compensation and protection to persons and families has come to its present status from early statute law, common law, and the concept of liability. Evolving from this history was the Occupational Safety and Health Act, which became effective in 1971 and whose passage was aimed toward these ends:

To assure safe and healthful working conditions for working men and women: by authorizing enforcement of the standards developed under the act; by assisting and encouraging the State in their efforts to assure safe and healthful working conditions by providing for research, information, education, and training in the field of occupational safety and health; and for other purposes (Public Law 91-596, 1970).

The importance of accident prevention should not be underestimated. According to Accident Facts (NSC 1996), the leading causes of death in 1993 for all ages and both sexes were heart disease (743,460 deaths), cancer (529,904 deaths), and stroke (150,108 deaths). However, among persons of all ages, unintentional injuries were the fifth leading cause of death. Motor vehicle accidents claimed 41,893, falls killed 13,441, poison took 7,877, drowning killed 4,390, and fires and burns killed 3,900; all other unintentional injuries resulted in the deaths of 19,322. Of these 19,322 deaths, 548 deaths resulted from electric current (shock). The number of fatalities due to electric current is actually higher, since electrical arcing can ignite fires and explosions and since withdrawal reflexes from shock can result in falls. These electrical dangers are quite pertinent to the psychophysiological laboratory.

### Safety Considerations for the Laboratory

OSHA maintains a website, the Computerized Information System (http://www.osha-slc.gov/), from which may be obtained current information regarding guidelines, standards, publications, and workplace violence. Here we provide safety checklists based on OSHA publications, information from the Centers for Disease Control, and other sources applicable to the psychophysiological laboratory.

### OSHA AND THE ACADEMIC LABORATORY

According to Blanton (1988), the Occupational Safety and Health Act of 1970 did not contain recommendations for the academic laboratory. It was not until accidents occurred in the 1970s—in which students on several campuses were burned and another student at Columbia University complained that he was being exposed to high levels of radiation in a physics laboratory—that OSHA began an investigation. The result was that OSHA began to take a more active interest in academic laboratories.

OSHA’s attention was directed at two broad areas: concerns with “substances themselves, such as explosion, fire, and runaway reactions; and those arising from the interaction between substances and lab users, such as poisoning, contamination, and asphyxiation” (Blanton 1988, p. 15). At the time, compliance of colleges and universities to OSHA safety standards was already suspect (Steere 1973). A survey by Blanton (1988) tried to determine the cause of low compliance. Thirty-eight colleges and universities were contacted and questioned regarding problems with compliance. The problems cited most were:

1. Safety budgets were too low for compliance;
2. Vagueness and sometimes conflicting regulations;
3. Excessive paperwork;
4. Difficulty in trying to keep current with OSHA’s changing standards; and
5. The lack of experience of OSHA inspectors in dealing with the research and teaching workplace.

Departments do not generally have safety budgets, and compliance would require the use of important teaching or research funds. Trying to keep current on OSHA regulations is not considered a priority for many departments, if they are even aware of OSHA standards. One might ask, Who is to do the necessary paperwork—a departmental secretary, a teaching assistant, a senior or junior professor, a special hire for the purpose? Those familiar with academic departments recognize the difficulties for each of these choices. The job may go unfulfilled unless your institution has a safety office or officer. A special assignment within an academic department would probably be resisted.

OSHA standards are often revised. On July 1 of each year, new standards are published; these July 1 standards are the new legal requirements and accordingly should be used. Earlier we referred to the OSHA website, which is continuously updated and can be consulted to obtain the most current information. Still, it is the latest July 1 published standards that are binding. Finally, note that research and teaching institutions have quite low priority within OSHA; the standards have generally been written with industry and business as the primary source of concern.

We have tried to select standards that are applicable to the psychophysiological teaching and research laboratory and that, with some commitment, will make these laboratories a safer place. By reviewing these standards, investigators can become more knowledgeable regarding
safety in the laboratory in their own institutions and perhaps become advocates for improved safety.

**BUILDING AND LABORATORY**

General requirements believed to be applicable to the laboratory and the building housing the laboratory are presented next. The requirements presented in this section are based on OSHA standards and can be utilized as checklists to assess general safety. Many items in the given tables can be evaluated via a walk-through by the appropriate authority. Who has this authority may not be obvious, but possibilities include the institutional safety officer, the departmental chair, and the laboratory supervisor. This walk-through is highly desirable because it shows a commitment to safety by supervisors and administrators to laboratory personnel. It is further suggested that periodic inspections be carried out to determine whether any new safety hazards have developed and to demonstrate a continuing commitment to safety.

**Building and Laboratory Safety: General**

Table 1 presents safety requirements that can be assessed by a simple walk-through; records should be kept of compliance and discrepancies. Where hazards are noted, every effort should be made to eliminate them.

Items 1, 6, 8, 10, 11, 12, 14, and 15 of Table 1 should be provided in the design of the building. Attempt to make corrections, if this has not been accomplished. For compliance with item 2, it should be noted that there are standard hazard signs for posting. Hammer (1989) discussed some of the properties for warning devices for each of the senses (vision, hearing, etc.). Item 3 addresses emergency evacuation in case of fire, chemical spills, or other emergencies in which rapid egress is necessary. During fires, smoke can restrict vision and exit doors can be confused with nonexit doors. The necessity for clearly marking these exit doors is obvious but not always done. Moreover, some persons do not function well during emergencies and so guidance needs to be obvious and unambiguous for exiting an area. Keeping areas clear (item 9) for freedom of movement protects personnel during emergencies and tends to decrease bruises, abrasions, cuts, and head trauma. Impress on laboratory personnel the necessity for keeping passageways clear and the laboratory neat and orderly. Minor inspections for item 9 can be accomplished each time the supervisor enters the area.

<table>
<thead>
<tr>
<th>TABLE 1. Building and Laboratory: Safety Checklist</th>
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<tbody>
<tr>
<td>1. Provide exits sufficient for prompt escape in the case of emergency.</td>
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<tr>
<td>2. Post appropriate signs for such items as harmful radiation, biohazards, microwave, room capacities, and exits.</td>
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<tr>
<td>3. Any door that is not an exit but could be mistaken for an exit must be marked NOT AN EXIT.</td>
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<tr>
<td>4. Keep all laboratory areas — including storerooms — in a clean, orderly, and sanitary state.</td>
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<tr>
<td>5. Keep all work surfaces dry. Floors should be slip-resistant.</td>
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<tr>
<td>6. Provide illumination adequate for the laboratory work being done.</td>
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<tr>
<td>7. Keep all aisles and passageways clear and with adequate headroom.</td>
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<tr>
<td>8. Provide elevated surfaces of more than 30 inches (76.20 cm) above the floor or ground with standard guardrails.</td>
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<tr>
<td>9. Stacked supplies, equipment, and materials should be stacked to prevent tipping, falling, rolling, spreading, or collapsing.</td>
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<tr>
<td>10. All exit signs are to be marked and illuminated with a reliable light source.</td>
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<tr>
<td>11. Provide directions to exits with visible signs if point of exit is not apparent.</td>
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<tr>
<td>12. Exit signs must have lettering at least 5 inches (12.7 cm) high, with each letter at least 1/2 inch (1.27 cm) wide.</td>
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<tr>
<td>13. Do not block exits.</td>
</tr>
<tr>
<td>14. Doors on cold storage rooms must be provided with an inside release mechanism even when the door is locked from the outside.</td>
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<tr>
<td>15. If a door between two rooms swings in both directions then install a viewing panel.</td>
</tr>
<tr>
<td>16. Written standard operating procedures must be available for the use of laboratory equipment.</td>
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</table>

Item 13 is also important: stacking boxes or other items against the outside of exit doors is easy to do for the unwary. In one case, a rug placed outside an exit door was too thick for the door to open wide enough for exit; the door would open several inches and then bind, completely blocking the passage. To correct this simple oversight required several phone calls, and two weeks elapsed before correction. Item 16 requires the laboratory supervisor to provide written instructions for the use of equipment and suggests that personnel be trained in its use. Particularly in academic settings, many students do not understand the principles of operation of important pieces of equipment. Also, the number of students using the equipment is often large and frequently changing. The necessity of adequate training under these conditions is a constant; printed instructions and training should be of high priority.

**Gas Cylinders**

The psychophysiology laboratory may have need of pressurized gases for a variety of purposes, including compressed air for cleaning and the use of oxygen and nitrogen with metabolic carts. Hammer (1989) discussed hazards associated with compressed gases and their enclosing cylinders: explosions, the cylinder as a fast-moving projectile, the whipping motion of lines and hoses connected to the cylinder, the cutting and penetrating action on the flesh of gas under pressure, and of course the toxic and explosive
TABLE 2. Compressed Gas Cylinders: Safety Handling

1. Compressed gas cylinders must be regularly inspected for obvious defects, deep rusting, and leakage.
2. Be especially careful of damaging safety valves and relief valves when handling and storing.
3. Keep cylinders away from heat, elevators, stairs, and gangways.
4. Mark empty cylinders and close their valves.
5. In places where cylinders are in use or stored, post signs reading DANGER – NO SMOKING, MATCHES, OR OPEN LIGHTS.
6. When moving cylinders, remove regulators and put on valve protection caps.
7. Use red to identify fuel gas hoses, green for oxygen hoses, and black for inert gas and air hoses.
8. Cylinders with water weight over 30 pounds (13.5 kg) must be equipped with a valve protection device or with a collar or recess for valve protection.
9. Cylinders must be marked to clearly identify their contents.
10. Place valve protectors on cylinders not in use.
11. Close cylinder valves before moving the cylinder, when the cylinder is empty, and when the cylinder is not in use.

Effects of some gases on escape. Hammer presents a strong case for securing cylinders:

Spectacular accidents have occurred when such charged cylinders were dropped or struck so the valve breaks off. The cylinder would then take off, in some cases smashing through buildings, rows of vehicles, and creating tremendous havoc that a heavy steel projectile traveling at high speeds can generate. Computations indicate that if a valve is broken off, a cylinder filled to 2,500 psi can reach a velocity of 50 feet per second in 1/10 second. (p. 327)

The use of gas-containing cylinders requires special precautions. In order to be useful, the gas pressure contained in the cylinders must be greater than the surrounding pressure, usually atmospheric (14.7 psi at standard temperature at sea level). Pressure within the cylinder can overcome the containing cylinder or cylinder valves and result in dangerous explosions or hazardous leaks. The pressure within vessels will increase in a nonlinear manner with increasing temperature, which can result from storage in a warm environment produced by the sun, space heaters, or radiators. For example, the vapor pressure of carbon dioxide at 70°F is 835 psi; “doubling” the temperature (to 140°F) more than triples the vapor pressure – to 2,530 psi. Special precautions must always be used in dealing with substances under pressure, and only qualified persons should attempt to repair, remove, or install lines and valves. Table 2 presents OSHA standards for the safe use of pressurized gas cylinders pertinent to the psychophysiological laboratory.

Fire Safety

According to the National Safety Council (1996), there were 6,588 deaths in the workplace in 1994 from all causes. Of these, 105 were due to fire and 97 were caused by explosions; this is 1.6% and 1.4% (respectively) of all deaths due to accidents. There is always a chance for fire to begin in the laboratory when electrical apparatus is operating or when combustible materials are present. Using data from The National Fire Protection Association Standards (1990), Hoelte and colleagues (1993) reported that, between 1986 and 1990, there were 101 fires annually in healthcare laboratories and 68 in chemical or medical laboratories, resulting in a total of 13 worker injuries and $1,522,000 in property damage. These data do not include many other types of laboratories conducting research in university settings or laboratories not classified as primarily chemical or medical. Hoelte et al. (1993) also reported that the major ignition source was a short circuit or ground fault (discussed later in the section on electrical safety). Fire safety is very important both for the laboratory worker and for participants in research projects. Table 3 lists safety guidelines and standards consistent with OSHA requirements, and it can be used as a safety checklist. It is also important to consult with local codes and your safety officer regarding compliance, as local codes may be different for your laboratory. An interesting question to pose is whether your safety officer has any idea of the type of equipment and substances you are using, particularly if you are not in a hospital or chemistry laboratory. (See Table 1 for general building and laboratory safety requirements.)

We now comment more extensively on some items listed in Table 3. Item 3 regulates the use of fire extinguishers. Fire extinguishers are not required if the employer has established and implemented a written fire safety policy that requires immediate and total evacuation from the workplace on the activation of an approved fire alarm. Item 4 designates the appropriate type of fire extinguisher for different hazards. OSHA standards require that the distance of travel to a type-A extinguisher for type-A hazards be 75 feet (22.9 m) or less and 50 feet (15.2 m) or less for type-B hazards and extinguishers; type-C extinguishers are to be located in a pattern that is appropriate to the area and to the distribution of class-A and class-B hazards, and type-D extinguishers need to be placed within 75 feet (22.9 m) or less from class-D hazards.

Item 5 is particularly important in the academic laboratory because some of the personnel (undergraduate and graduate students) are transitory; thus, a regular training program needs to be maintained whenever new persons join the laboratory team. Items 6 and 7 are especially important in the student environment. A fire extinguisher is a life- and property-saving apparatus, but it may be stolen or utilized for other purposes. The laboratory supervisor
must determine that the fire extinguishers are fully charged and that the plastic or wire loop on each trigger is intact.

Item 9 needs to be coordinated with your local safety officer or department, if you have one; if not, then the laboratory supervisor is responsible. Items 10 and 11 are the responsibility of the safety officer, safety department, or building supervisor. However, the laboratory supervisor can assume responsibility for determining whether the evaluations are being carried out. Help on items 12-17 can be obtained from the commercial suppliers who manufacture the hazardous material you may be using. These suppliers can also help choose storage containers for the material.

**EMERGENCIES**

Planning for emergencies, following safe practices, and designing safe buildings and laboratories is the best preparation for emergencies. Emergencies can occur in the laboratory owing to a number of hazards: fires, explosions, radiation, contact with electrical current, chemical spills, contact or release of pathogens, traumatic injuries to persons, earthquakes, floods, power failure, and one of the latest recognized hazards - workplace violence. In addition, in the psychophysiology laboratory there are cardiovascular risks due to the imposition of stressful psychological or physical conditions. Space limitations restrict treatment of each of the particular hazards, but additional discussion can be found in Hammer (1989) and Keith (1990). In later sections, specific guidelines will be given regarding electrical current, blood-borne pathogens, and cardiovascular risk, since these dangers are more prevalent in the psychophysiology laboratory. In this section we will give general guidelines and standards regarding preparation for - and response to - emergencies. More comprehensive treatments can be found in two manuals produced by OSHA (1992, 1995b) and in Hammer (1989) and Keith (1990). Much of the information presented here is based on these writings.

One of the first questions to be asked and answered by the laboratory director is: What are the hazards for which preparation is necessary? Answering this question will require a "hazards inventory" of the laboratory. Keith (1990) discussed several hazards that are likely to be found in a laboratory: chemical spills, fire, explosions, toxic gas release, and radioactive or biological contamination. We might add the danger of cardiovascular incidents, contact with electrical current, and workplace violence. Hence, the first step in planning for emergencies is to determine what type of emergencies the laboratory is likely to incur.

After the hazards inventory, the next step is developing a written plan of action for each identified type of emergency. This plan should be kept in a central file, and all laboratory personnel should receive a copy. The plan is to include Material Safety Data Sheets for all toxic substances used. These forms are available from the manufacturer and specify precautions regarding handling, storing, and using the material; they also outline emergency and first-aid procedures. It is advisable that the written plan include a rewriting of the data sheets in simple language so that all persons involved can understand them. You should check with your institutional safety officer or safety department, who may have special procedures in place for clean-up of the materials you are using. The written plan must give in detail what is expected of each category of person in the laboratory. Responsibilities range from administering first aid to clean-up or simply sounding the alarm and then
leaving the area. For industry, OSHA (1995b) stipulates that, at a minimum, the written plan must contain:

(1) emergency escape procedures and emergency escape assignments, (2) procedures to be followed by employees who remain to perform (or shut down) critical plant [read "laboratory"] operations before the plant is evacuated, (3) procedures to account for all employees after emergency evacuation has been completed, (4) rescue and medical duties for those employees who are to perform them, (5) the preferred means for reporting fires and other emergencies, and (6) names and regular job titles of persons or departments to be contacted for further information or explanation of duties under the plan. (p. 1)

We also view these six items as the minimum; additional features may be required in light of the discussion in this section. The emergency plan needs to be reviewed with laboratory personnel at its inception, when changes to the plan are made, and with all new laboratory workers. It is necessary to assign responsibilities to laboratory personnel. Someone needs to be designated as the in-charge person during all laboratory operations. Specific duties and responsibilities must be spelled out to avoid confusion.

After potential hazards have been identified, Material Safety Data Sheets have been obtained, and a plan has been written and distributed to laboratory personnel, the next step is to train all laboratory personnel regarding (i) every potential hazard to which they might be exposed and (ii) how to protect themselves and laboratory participants. After training, the laboratory director has the responsibility of ensuring the effectiveness of such training. Ideally, this would entail practical examinations and written tests. Review the training and testing for each regular laboratory worker at least twice each year. For all new laboratory personnel, have them undergo the training as soon as they become working members of the laboratory. Different hazards require different plans of action. At the least, personnel should: (a) alert others regarding the emergency; (b) activate the emergency plan relevant to the hazard; (c) contain or neutralize the hazard (or, if this is not possible, call the appropriate emergency numbers); and (d) evacuate the area, if necessary.

The following emergency scenario underscores the importance of designating responsibilities and the need for an emergency action plan. Two students are conducting a stress study, and the participant reports feeling faint and nauseated. The ECG (electrocardiogram) is being monitored and shows significant S-T segment depression (discussed later in the section on monitoring participant safety). Suddenly, the participant slumps forward and strikes her head on the edge of an amplifier; bleeding ensues, and she appears to be unconscious. What is to be done? Assume that both students have been trained in CPR (as they should have been) or even are first-aid certified. If one student has been designated as the in-charge person by the laboratory supervisor, then responsibilities can be carried out according to the emergency plan. The emergency plan can direct: (a) one person to begin CPR, if necessary; (b) the second person to stop the blood flow (first aid) following universal precautions (discussed in the section on preventing infection); and (c) one of the pair to call the emergency telephone number as soon as possible. Confusion will remain at a minimum if personnel have been trained and the line of authority is clear. Of course, the person using the telephone must know the laboratory room number and must be able to inform emergency personnel how to locate the room. The person telephoning – if not needed for CPR or blood flow control – can then move to a strategic location and direct the emergency team when it arrives. Other types of emergencies will likewise result in efficient action provided a plan has been developed, the lines of authority are clear, and each person knows what action to take according to the plan.

Table 4 lists other items to facilitate the emergency plan. Note the necessity of posting telephone and room numbers. Laboratory personnel need to be familiar with the location of the nearest telephone. The suggested posting must be clearly visible at the telephone and other locations in the laboratory, and it should display the following.

1. Telephone number of the laboratory or the nearest telephone.
2. Room number(s) of laboratory.
3. Directions to the laboratory from the nearest main street and the name of that street.
4. A listing of laboratory personnel with their telephone numbers and titles:
   a. laboratory supervisor;
   b. laboratory assistant supervisor;
   c. laboratory personnel.
5. Emergency telephone numbers:
   a. 911, if this service is available;
   b. institutional safety officer or department;
   c. security;
   d. local police department;
   e. local fire department;
   f. nearest medical aid.
6. Location of laboratory first-aid kit (or nearest first-aid kit).
7. Person certified to administer first aid for the laboratory and telephone number.
8. Places of exits from laboratory and building.
9. Place where "spill kit" packages are stored (if available), or name and telephone number of the individuals responsible for spill clean-up.
10. Location of fire alarms (if any).
11. Warning that elevators are not to be used during emergencies.

Basic Safety Training for Laboratory Personnel

We have covered the necessity of developing a safety plan for the laboratory. It was also noted that laboratory
personnel should receive training on the plan and should practice emergency responses as specified in the plan. In this section we describe the specific skills and information that are required for safe laboratory operation.

Cardiopulmonary Resuscitation (CPR). All personnel should receive CPR training and have in their possession a valid card. The training can be obtained from either the local fire department or Red Cross chapter. Hospital employees can usually become certified at their place of employment. The CPR card is valid for one year and must then be renewed. The laboratory supervisor should keep a photocopy of this card on file.

First Aid and Safety. First-aid training is advisable and is available from your Red Cross chapter. All laboratory personnel are advised to obtain such training. The first-aid card is valid for three years and then must be renewed. Photocopies of these cards should also be kept on record.

Basic Electricity and Electronics. We recommend that a basic understanding of electricity be obtained. Training gives laboratory personnel a better understanding of the dangers involved in working with electrically powered apparatus and forewarns against making errors. In later sections, we discuss working more safely with electricity and point out errors likely to be made (but we do not cover electricity basics). For basic theory we recommend Marshall-Goodell, Tassinari, and Cacioppo (1990) or Simpson (1995).

Laboratory Apparatus. Each laboratory will have a unique configuration of apparatus for its research needs. Each member of the laboratory should have an understanding of the operation of the equipment, the physiological response that it measures, and basic trouble shooting for malfunction. Such information will result in more reliable and valid data recording, help the operator to detect improper apparatus function, and guide the researcher in determining the difference between equipment malfunction and anomalous responses from participants.

Fire Extinguishers. If your laboratory is responsible for initial containment of fires, then training in the proper use of fire extinguishers is necessary. In addition, laboratory personnel need to be knowledgeable regarding the appropriate type of fire extinguisher for each of the different classes of combustible materials. Relevant information is printed on the fire extinguisher and should be in the emergency action plan. Consult with your fire department for information and advice as needed.

<table>
<thead>
<tr>
<th>TABLE 4. Emergency Preparation Checklist</th>
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</thead>
<tbody>
<tr>
<td>1. Post emergency telephone numbers where they can be seen easily.</td>
</tr>
<tr>
<td>2. Post the room number(s) of the laboratory and have a written description of how emergency personnel can locate the laboratory.</td>
</tr>
<tr>
<td>3. Know the location of the nearest hospital, clinic, or infirmary for medical care. Know what arrangements have been determined for transport to that facility or develop such arrangements.</td>
</tr>
<tr>
<td>4. All laboratory personnel who are expected to respond to medical emergencies should: (a) be first-aid certified; (b) have had hepatitis-B vaccination; (c) have had appropriate training to protect themselves from blood-borne pathogens, including universal precautions; and (d) have available and be able to use appropriate protective gear (e.g., gloves and masks) for protection against blood-borne pathogens. OSHA has determined that individuals who give first aid as only an ancillary part of their laboratory work need not have pre-exposure hepatitis-B vaccination. However, following exposure to blood or other potentially infectious materials, the incident must be reported and the exposed individual must be offered the opportunity for hepatitis-B vaccination within 24 hours of the incident.</td>
</tr>
<tr>
<td>5. Following exposure, an immediate medical evaluation and then a medical follow-up is necessary.</td>
</tr>
<tr>
<td>6. Medically approved first-aid kits should be made available in the laboratory. The kits must be inspected periodically and supplies replenished when necessary.</td>
</tr>
<tr>
<td>7. In laboratories working with toxic or corrosive materials, a quick flush system must be available for the eyes and body.</td>
</tr>
<tr>
<td>8. Develop a comprehensive emergency plan.</td>
</tr>
</tbody>
</table>

Cardiovascular Risk. Many laboratories intentionally stress participants for research purposes. These stressors are usually benign for the healthy person; with participants who are at risk for cardiovascular or health problems, emergencies are more likely to occur. These concepts are covered at length in a later section, which also lists agencies offering advanced training. However, if at-risk participants are to be processed, then special training and certification should be obtained or a certified person should be present in the laboratory with the necessary emergency equipment.

Universal Precautions. If laboratory personnel must handle blood or other potentially infectious materials, then familiarity with universal precautions is necessary (see the section on preventing infection).

Auditory Stimuli

Auditory stimuli are utilized in the psychophysiological laboratory for several purposes: conditioned stimuli, unconditioned stimuli, masking, startle, discrimination learning, and signal detection. Our concern is the intensity with which these stimuli are presented. Intensity of auditory stimuli is measured with a sound pressure level (SPL) meter, which is designed to measure sound intensity in decibels (dB). An intensity of $10^{-12}$ W/cm² corresponds to
the threshold of hearing for a 1,000-Hz sine wave tone. Decibels are defined as follows:

\[
\text{number of decibels} = 10 \log_{10}(I_w/I_{W T}),
\]

where \( I_w \) denotes intensity (in watts) of the stimulus and \( I_{WT} \) is the hearing threshold as just defined. Evaluating this equation shows that the threshold for hearing at 1,000 Hz is 0 dB. Normal speech is about 60 dB, heavy traffic is about 100 dB, and a large jet engine at 22 m is about 120 dB. An SPL meter has three basic scales (A, B, and C) as well as fast and slow response times. The human ear is less sensitive to low-frequency sounds. The A scale approximates the response of the human ear by attenuating low frequencies in measuring dB level; most measurements of auditory stimuli for humans utilize the A scale. The slow scale responds more slowly to peak intensities. Because we are concerned with these peak intensities for sudden onset (startle) tones, it is necessary to use the fast scale when measuring very short-duration stimuli with rapid rise times.

**NOISE EXPOSURE LIMITS**

In order to avoid damage to hearing, limits on noise exposure have been established by OSHA. In the psychophysiology laboratory the use of noise for experimental purposes and the gathering of data in noisy environments require that investigators be aware of limits of exposure and follow OSHA standards and guidelines. Assessment of noise exposure requires evaluating both the intensity of the noise and its duration. Table 5 presents the exposure limits beyond which a person must wear protective hearing devices. The left column presents the time of exposure in hours for a given intensity of noise; the right column shows the intensity. All measurements are taken with an SPL on scale A with slow response time. For example, a person exposed to 90 dBA for 8 hr or more in a working day must wear hearing protectors that reduce the noise to 85 dBA (as specified by OSHA, which also reviews acceptable attenuators). However, most exposures to noise are not of constant intensity. Thus, assessing noise exposure requires a “daily dose” (DD) measure of noise, which is calculated as follows:

\[
\text{DD} = (C_1/T_1 + C_2/T_2 + \cdots + C_n/T_n) \times 100,
\]

where \( C_n \) denotes the total exposure at a specified noise level and \( T_n \) is the total time of exposure at that noise level. If DD exceeds 100 then noise attenuators must be worn. OSHA also stipulates that any worker exposed to noise at 85 dBA for an 8-hr period must have a baseline audiogram completed within six months of the first exposure. If a specified hearing loss is detected at the twelve-month follow-up, then attenuators are required. A hearing loss (standard threshold shift) is defined by OSHA as an average drop of 10 dBA or more at 2 kHz, 3 kHz, and 4 kHz in either ear. Annual audiograms are then required for comparison against the original baseline. Recent OSHA recommendations may change the requirements from 85 dBA to 82 dBA both for required testing and for noise attenuators. If your laboratory may be subject to these standards then the latest OSHA requirements should be consulted. A general discussion of noise exposure can be found in NIOSH (1972).

**IMPACT NOISES**

No sound should ever be presented to a participant with an intensity of 140 dB or more. Such intense noises can permanently damage the hearing mechanism. Although the ear has a built-in protective reflex to dampen loud sounds, this reflex requires 80 msec to operate (Guyton & Hall 1996) and cannot protect against such intense noises. Because of experimental data (Henderson et al. 1991) and the earlier recommendations of NIOSH (1972), OSHA will probably recommend that unprotected noise exposure at or above 115 dBA not be allowed. We have reviewed recent literature on the utilization of sound stimuli in the journal *Psychophysiology* and found that the proscribed level has not been used. During 1997, the loudest sound used was 110 dBA of 1-sec duration (Gautier & Cook 1997); in 1996, the most intense was 106 dB in 50-msec bursts of white noise (Bradley, Cuthbert, & Lang 1996). These short durations at the intensities used are within the OSHA guidelines. All things considered, it is reasonable to limit exposure to intensities no greater than 115 dBA.

**Electrical Safety**

The National Safety Council (1996) estimates that the total number of deaths due to “contact with electrical current” was 346 out of a total of 6,588 workplace deaths in 1994, making up 5.3% of fatalities. As the titles of the various chapters in this *Handbook* suggest, it is not

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**TABLE 5. Comparison Table of Daily Duration to Allowable Sound Level**

<table>
<thead>
<tr>
<th>Daily Duration (hours)</th>
<th>Allowable Sound Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.0</td>
<td>90</td>
</tr>
<tr>
<td>6.0</td>
<td>92</td>
</tr>
<tr>
<td>4.0</td>
<td>95</td>
</tr>
<tr>
<td>2.0</td>
<td>100</td>
</tr>
<tr>
<td>1.0</td>
<td>105</td>
</tr>
<tr>
<td>0.5</td>
<td>110</td>
</tr>
<tr>
<td>0.25</td>
<td>115</td>
</tr>
</tbody>
</table>

*Note: Sound-level units are dBA, slow-response SPL.*  
*Source: Code of Federal Regulations (1996), Table G.16.*
possible to work in the area of psychophysiology without using equipment powered by electrical energy. The hazard of contacting electrical current is always present. This section will present several concepts requisite to understanding electrical hazards and the prevention of electrical accidents.

The damage caused by contact with electrical current can result in involuntary reflexes, burns, cardiac fibrillation, ventricular standstill (asystole), tissue and organ destruction, and death. Reflexes may lead to falls or forceful contact with other hazardous materials or with containers of those materials, leading to spills or fires. Burns result from the heat generated by short circuits, contact with overheated electrical elements, and the passage of high current levels through the skin or deeper tissue. Low levels of current passing through the heart can result in cardiac fibrillation, and higher levels can result in complete cardiac arrest. Current passing through the respiratory muscles can stop the ability to breathe, and higher currents passing through the brainstem can damage the respiratory center and lead to asphyxiation even after the current is withdrawn. The sources of these currents reside in electrically powered apparatus, power lines serving that apparatus, static electricity, and (infrequently) lightning strikes entering equipment or laboratory when buildings or apparatus are improperly grounded.

PROTECTION AGAINST SHOCK: INTRODUCTION

Several strategies may be used to reduce the hazard of contact with injurious electrical current. As mentioned earlier, the possibility of contact always exists when working with electrically powered equipment. In this section we will present means to increase safety by several routes: use of battery-powered equipment, optic fiber connections, electrical isolation, grounds and grounding, ground fault interrupter circuits, double insulation, and minimizing the possibility of injury by lightning strikes.

Use of Battery-Powered Equipment

The battery voltages used to power electrophysiological monitoring equipment are generally quite low, usually 9 V DC or less; current flow through the skin is therefore minimal. Cleaned, abraded, intact skin may have as few as 5,000 ohms between recording electrodes. All 9-V battery voltage applied to the recording electrodes would only produce a current flow \( I = E/R \) of 1.8 mA. Batteries are completely isolated from ground, so no current can flow from battery to ground. Battery-operated equipment is very safe, but there are disadvantages and some dangers. Remember that pacemakers and implantable defibrillators for the heart can apply a brief voltage to keep the heart operating and can reverse a fibrillating heart; the circuits powered by the battery step up the voltage, thereby dropping the current. However, once the protective skin layer is broken, impedance drops precipitously and even a 9-V battery supplying current across the heart is unsafe. Furthermore, battery-powered devices may be connected to recording devices that are usually line powered, so the safety features of the battery can be defeated unless isolating or current-limiting circuits are used. Batteries need recharging or replacement, which can prove inconvenient and incur extra costs. Finally, some batteries will explode if improperly connected to the charger or if overheating occurs. For example, in 1979 the Federal Aviation Administration disallowed the use of all lithium sulfur dioxide batteries in U.S. registered aircraft because of several explosions (Hammer 1989).

Optic Fiber Connections

Another safety option is to connect the participant with sensors that are coupled to amplifiers by optical cables. Using this method, no shock is possible. The fiber optical cables are nonconductive – light is used to carry the information from the subject to the amplifiers. This method gives protection from shock due to accidental ground contact and avoids ground loops (shock from contact with ground and ground loops is discussed two sections hence). However, special circuits are required for optical amplifiers. Also, because no ground contact is used, the signals can be quite noisy in an electrically active environment.

Electrical Isolation

Electrical hazards may be reduced by isolating the participant from ground. In the psychophysiology laboratory this technique is made more difficult when the participant is connected directly to the monitoring apparatus. Isolation transformers separate energized equipment from the grounded primary circuits of the transformer. Therefore, the inadvertent touching of a “hot” source and any earth ground by the experimenter or the participant does not result in a shock, since there is no pathway back to earth ground. Isolation transformers may be purchased for just this purpose. Some commercial equipment is designed with isolation circuits already installed. The popular Minnesota Impedance Cardiograph™ uses such circuitry. When purchasing equipment, determine if the apparatus is designed with isolating circuitry.

When using an isolated circuit, shock hazards are still present. If a person contacts both the hot wire and the neutral wire of an isolation transformer, a shock will be delivered. Unqualified personnel should not attempt repairs. Apparatus should be de-energized when being repaired, connected to, or disconnected from other energized equipment. A second danger occurs if a conductor from the secondary system accidentally contacts ground. Because there is no return path to the grounded neutral of the line power in an isolated system, usual protective devices like fuses or circuit breakers do not operate. Hence,
if the second conductor contacts ground, "a short circuit will occur with possible disastrous consequences, such as ignition of ether vapors by arc or a lethal shock to personnel" (McPartland & McPartland 1996, p. 1121). Therefore, an ungrounded isolation system must give visual and auditory warning if such a contact to ground occurs. Suppliers can give the necessary specifications of transformers for a particular laboratory use. You should determine whether the isolation transformer is constructed with the necessary warning alerts should a ground contact occur.

**Grounds and Grounding**

Electrical service systems for most laboratory apparatus appear at the electrical receptacle into which cords are plugged for powering apparatus. The voltage is about 120 V AC in the United States and Canada. The plug is generally three-pronged and of a standard configuration. The small short blade contacts the ungrounded or "power" source and the wider blade contacts the grounded side of the power source in the receptacle. The plug inserted into the wall receptacle carries current to the resistance loads in the apparatus. The third pin on the plug makes contact with a conductor in the receptacle that leads back to the grounded side of the receptacle and to physical grounds: this pin is the grounding pin. This grounding pin is longer than the other two pins and is U-shaped. Because of this configuration, the plug can be inserted only one way, and the grounding U-shaped pin is the first to make contact when inserted and the last to make contact when the plug is removed. The grounding pin detects ground faults and protects participants, operators, and equipment. The use of a grounding pin should never be circumvented by using a "cheater" adapter that permits use of a three-pronged plug with a two-slot receptacle.

A ground fault is said to occur when an unwanted connection is made between a power-carrying conductor and ground. When such a contact is made the object of the contact rises to the voltage level of the power source. For example, if the ungrounded current-carrying conductor in a piece of apparatus were frayed and contacted the equipment housing, the housing would rise to the voltage of the power conductor. Such contact can also be made from insulation breakdown or a broken power wire. Figure 1 shows two different conditions and the danger involved to a person contacting a faulted system. The sink is connected to earth ground through cold-water pipes with a very low-resistance path to earth. Part A of the figure shows apparatus with a power line directly touching the metal part of the chassis. Note that the chassis is connected to earth ground by way of the grounding conductor of the third pin and also is connected with the grounded conductor (not shown). When the fault occurred, the current-carrying capacity of the circuit breaker or fuse (usually 20 or 30 amps in the laboratory) was exceeded and opened, thereby removing the fault: the chassis fell to ground potential. A person touching the apparatus and a ground, such as the sink, would not be shocked. The opening of the circuit protection device can easily be shown by Ohm's law: \( I = \frac{E}{R} \). Assume that the voltage \( E \) at the receptacle is 120 V and that the resistance \( R \) of the chassis to ground is very low, about 1 ohm. The resulting current flow is 120 A, enough to open the circuit protection device immediately.

Now examine Part B of Figure 1, where the ground wire to earth is broken or nonexistent. What happens to the person touching the faulted chassis that has risen to 120 V? First, the equipment will continue to operate, since no large currents are detected by the circuit protector. The theoretical minimum resistance between the two hands is part of the apparatus. Figure 1. Part A: A fault has occurred between the hot wire and the chassis; the grounding wire is intact and the circuit breaker or fuse is opened, and the person is not shocked. Part B: The grounding wire is broken, no fault is detected, and the person receives a dangerous shock.
500 ohms; the actual resistance is usually higher. If we use a more reasonable value of 1,500 ohms, then what is the amount of current flowing between the two hands and across the heart? Again using Ohm’s law, we see that $I = \frac{V}{R} = \frac{80}{1500} = 0.053$ mA. This 0.053 mA is a very dangerous shock and is within the range for initiating ventricular fibrillation. The 80 mA is much too small to activate the circuit protector, which requires 20 or 30 amps to open. If the person cannot let go of either the sink or the chassis then the person’s resistance will drop even further, and current through the body and across the heart will rise.

To increase safety in the laboratory, all equipment grounding, terminals, insulation, and plugs should be checked at least twice each year (Moak 1994). We present a checklist for electrical safety in a later section. On a daily basis, it only takes a moment to determine whether grounding is intact before operating equipment.

**Ground Fault Circuit Interrupter**

The ground fault circuit interrupter (GFCI) should be utilized in all laboratories where the possibility exists for either the experimenter or subject to contact both the power side of electrical lines and ground – in Figure 1, this was indeed the case. The GFCIs should be installed to serve as the interface between the receptacle and the power cords supplying the equipment. In fact, GFCIs are required by electrical codes if receptacles are near cold-water pipes or water that contacts drains. It is preferable to have the GFCIs installed during laboratory construction. Figure 2 shows the mechanism of action for a GFCI. The current drawn from the power source is compared with the current returning. If a discrepancy as small as 5 mA is detected by the sensing circuit in the GFCI, the power output of the GFCI is interrupted in as little as 25 msec. Figure 2 depicts a ground fault between power and a grounded tank. If we replace the tank with a person, it can be seen that the GFCI will stop current flow through the person and prevent a severe shock.

Figure 2. The ground fault circuit interrupter senses the difference between current flowing out of the power source and current returning. If a difference of 5 mA or greater is detected, power is shut off within 5 msec. Redrawn from OSHA (1983), *An Illustrated Guide to Electrical Safety*, p. 109.

**Double Insulation**

Double insulation is built into some tools and appliances (e.g., heaters, toasters, hand drills). Devices with double insulation do not have a grounding conductor to any of the conducting but non-current-carrying surfaces, so only a two-pronged plug is used to access wall receptacles. Double insulation means that, in addition to functional insulation (like the winding on a coil), there is also installed a second insulation designed to protect the user if the functional insulation should fail. If you intend to use a device that has only a two-pronged plug, first determine that the device has been approved by a recognized safety agency like Underwriters Laboratories (UL 1983).

**OTHER CONCEPTS AND CONSIDERATIONS**

Several miscellaneous considerations regarding electrical safety are presented next: ground loops and leakage current; the physiological effects of current; electrical polarity; lighting strikes; and current limits.

**Ground Loops and Leakage Currents**

Electrical charge differentials always seek to neutralize by current flow from a higher voltage to a lower one; paths to ground are one such neutralizing process. Unwanted paths can occur through: (a) frayed wiring; (b) insulation breakdown due to aging, heat, contact with corrosive chemicals, or mechanical abuse; and (c) damp or wet environments. Capacitive coupling will also induce current flow in normally non-current-carrying parts of apparatus. Any contact made between the higher voltage source and
ground through any of these means will result in current flow. If the person becomes the path, shock can occur.

Another, more subtle path for current flow occurs when two or more pieces of apparatus are connected to ground at different resistances. In this case a ground loop can occur, and current will flow between the pieces of apparatus to ground if contact is made between the different devices. This contact can be made by the laboratory worker when two or more devices are touched simultaneously. Furthermore, if a laboratory participant is connected to the ground of different electronic devices with different resistances to ground, then current can flow through that individual. In addition, leakage current will flow through a subject if one piece of apparatus has a faulty ground connection.

One protection against such occurrences is to connect all pieces of apparatus to a common ground at one point in the laboratory. This can be accomplished easily by plugging equipment into a small strip outlet (but do not use multiple outlets that plug directly into the wall receptacle). The strip outlet must have a place for the ground on its plugs, and only the strip is plugged into the wall receptacle; of course, all receptacles on the strip must have a place for ground from the apparatus plug. One can measure the individual resistance of each (U-shaped) ground socket on the receptacle. Differences might be detected if a connection is loose or broken within the body of the strip. For safety, always make these measurements with the power strip unplugged from the power receptacle. To determine whether the apparatus has good ground connection, check the resistance between the U-shaped prong on the plug of the apparatus and the conductive surfaces of the apparatus (metal housing, screws, metal operating knobs, etc.). In both cases – power strip and apparatus surfaces to U-shaped prong – the ohmmeter should read a dead short: 0 ohms.

Finally, to establish whether the participant will be grounded on connection to the apparatus, determine the resistance between the ground lead (which will be attached to the subject) and the U-shaped prong on the power cord running from the device as follows. Unplug the power cord from the wall receptacle, and place one end of an ohmmeter on the ground probe of the plug and the other on the ground lead; if the measured resistance is 0 ohms then the participant will be grounded when attached. The subject will usually be grounded unless your apparatus is electrically isolated or battery-powered. Again, the importance of proper intact grounding of apparatus should be apparent.

Staessen (1994) indicated that the maximum leakage for hospital conditions – when a patient is connected to equipment – is 10 μA for source current and sink current. Source current is current that flows from connected apparatus through the person to ground; sink current (patient isolation risk current) is “current flowing from the patient to ground through a path applied to the patient due to the unintended introduction of a voltage from an external source on the patient” (p. 132). Leakage current maxima for enclosures of cord-connected apparatus remain at 100 μA under normal operating conditions and 300 μA under single-fault conditions, which include “open ground conductors; short circuit of either barrier or double insulation; failure of a single component; the application of line voltage on an isolated patient-applied part; the application of line voltage to an input or output part (or to accessible conductive hardware of the enclosure) of equipment that is not intended to be grounded” (p. 131). However, under single-fault conditions, only 50 μA are allowed for isolated patient connections and 100 μA for nonisolated connections.

If surface electrodes are to be used, then the psychophysiology participant should be treated as if in a hospital. Standard practice in the psychophysiological laboratory is to reduce skin resistance through cleaning and sometimes abrading. The protective skin resistance is purposely circumvented under some conditions, among which are: puncturing the skin for single-cell muscle fiber recording, using needle electrodes for electroencephalographic recording, and inserting indwelling catheters for automatic blood withdrawal and heparin injections. Finally, recording devices inserted into body cavities will reduce the electrical resistance between apparatus and participants. In all of these cases, adherence to appropriate low levels of leakage current (as prescribed by electrical codes) is necessary. Determine from specifications whether your laboratory equipment meets these standards.

The Physiological Effects of Electrical Current

Electrical current magnitudes that contact the body can range from the small microampere levels found in leakage currents to above 200 kA in lightning strikes. Small currents are quite likely to occur, whereas the larger currents of lightning require improbable circumstances (which do, however, occur each year). The following paragraphs enumerate the physiological effects of 60-Hz current when contact is made through intact skin (Bernstein 1994).

1. About 0.5 mA is the threshold of detection for electrical current. At this level, a small tingle is perceived.
2. At 5 mA, a definite shock is felt. This level may lead to involuntary muscle contractions and a vigorous withdrawal reflex from the electrical source. Some persons cannot let go at this intensity. The “let-go threshold” is the point at which involuntary contractions are so strong that the individual can no longer release the electrically charged object. If the person is not removed from the current then the skin impedance will continue to drop, with a simultaneous current increase.
3. At 6–25 mA (women) and 9–30 mA (men), the shock becomes quite painful and the let-go threshold is exceeded.
4. At 50–150 mA there is extreme pain. If the current is across the chest, then respiratory arrest will occur (owing
to involuntary tonic spasms of the respiratory muscles). Currents of 50 mA for 2 sec or longer can result in ventricular fibrillation. If current is not removed, death will follow. However, once fibrillation occurs, the heart seldom reverts unaided to its normal rhythm. Cardiac fibrillation is an uncoordinated twitching of cardiac fibers that generates no pumping action; CPR must be administered immediately and qualified help summoned.

5. At 500 mA, ventricular fibrillation can occur in only 0.2 sec.

6. At 1,000 mA, nerve and muscle damage occur, as well as cardiac arrest; death is highly likely. At this level, the heart will sometimes resume normal pumping action when current is removed — provided that excessive destruction of heart tissue has not occurred. Note that the lower current levels induce fibrillation whereas the higher levels induce cardiac arrest.

7. Above 10,000 mA, severe internal and external burns occur and death is most probable.

Maintaining Proper Polarity in Plugs and Receptacles

The use of receptacles, plugs, and connectors requires maintaining correct polarity between the ungrounded (hot) conductor, the grounded (neutral) conductor, and the grounding conductor. The insulation of the ungrounded conductor can be of any color except white or green. It is usually black and should be connected to the brass or black terminal on the plug (remember, “black to brass” or “black to black”). The grounded conductor must be connected to the light or nickel-colored terminal (“white or gray to light”). Finally, the grounding conductor (used to ground equipment and connected to the U-shaped probe) is to be green, green with stripes, or bare; it should be connected to the green hexagonal-head terminal screw. (Remember, “green to green” or “green to ground.”) Reversal of polarities puts the operator at risk for shock.

The most dangerous reversal occurs when the ungrounded (hot) conductor is inadvertently connected to the green hexagonal terminal on the plug, the grounding conductor is connected to the brass terminal, and the grounded conductor is properly connected to the light (nickel-colored) terminal. This reversal would result in the hot conductor energizing the housing of the equipment or tool. The circuit protector would not operate, and severe shock would occur if the operator touched the housing and any ground. A less serious but still hazardous situation occurs when the ungrounded and neutral conductors are reversed. In this case, the neutral wire would be placed across the On–Off switch of the apparatus. When the switch is Off, the hot wire would still be connected to the internal parts of the device. Probing inside the tool or apparatus could result in shock. Follow these guidelines when you find it necessary to replace a plug or to check on the polarities of plugs already rewired. Clearly understandable polarities are described and illustrated in *An Illustrated Guide to Electrical Safety* (OSHA 1983).

The laboratory worker assumes that the receptacles were wired correctly during building construction. Whether the receptacle has correct polarity is best left to a qualified electrician. However, safe plug-in testing devices (outlet circuit testers) are available in hardware stores. Skuggsvig (1992) reported the results of a survey in the homes of Underwriters Laboratories employee volunteers in the 1980s to determine the percentage of receptacles wired incorrectly. The results of the survey showed that 83% of the polarized receptacles were wired correctly; 6% were incorrectly wired polarized receptacles, and 11% were non-polarized.

**Comparison of the Physiological Effects of Different Frequencies**

Direct current is less hazardous (at the same amperage) than 60-Hz (alternating) current; the value needed to produce a startle reflex or ventricular fibrillation is about three times higher for direct current. Moreover, there is no let-go phenomenon for DC; instead of increases in muscular contraction with increases in amperage, as occurs in AC, the experience is increasing heat. However, the act of letting go of a DC line is extremely painful: as the body part is removed, the contact area decreases and amperage per unit area rises rapidly. Reilly (1992) combined data from several sources regarding the let-go current for DC. Whereas 99.5% of volunteers refused to let go of a DC wire at 99 mA, 99.5% of volunteers could not let go at only 22 mA AC. This relationship also holds for the startle reflex and ventricular fibrillation; that is, the amount of current for an effect is always higher for DC than AC.

The commonly used 60 Hz is most dangerous for mammals. In the range of 10–100 Hz, let-go current is approximately the same. However, below 10 Hz and above 500 Hz, the amount of current required for a given effect increases rapidly. For example, at 5,000 Hz the let-go current is about 65 mA, whereas at 5 Hz the let-go current is approximately 50 mA (Dalziel 1943, 1972). Considerably higher currents are required for physiological damage (and for the let-go threshold) as frequencies increase or decrease from 60 Hz.

**Lightning**

Grounding of systems and circuit conductors is required by the *National Electrical Code* (1996). That is, the electrical system and circuits supplying a building must be grounded and have a grounding system. The purposes of such grounding are (a) to limit voltages in the supply circuits and laboratory due to lightning, power surges from the supply, and unintentional contact with lines of greater voltage, and (b) to provide stability of power to ground during use. In addition, the grounding of conductors provides a path for activation of circuit protectors if a ground fault occurs.
Lightning strikes kill and injure persons around the world, and about 400 are struck each year (Bernstein 1991a). According to *Accident Facts* (NSC 1996), lightning in the United States was the cause of 75 deaths in 1991, 53 deaths in 1992, 57 deaths in 1993 and 72 deaths in 1994. The states with the highest casualty rates were Florida, North Carolina, and Texas. The nature of a lightning strike is one of high voltage and high amperage discharge. Lightning discharges occur from cloud to cloud, cloud to atmosphere, and cloud to earth or water. The strike may reach earth by a path through trees, ships, high points on the earth, buildings, towers, and animals. If you are conducting research outdoors during lightning discharges, all personnel must immediately seek low ground (such as ravines or gullies) or take shelter within buildings. As lightning strikes traverse an area, high points become a target for discharge. Seeking shelter under a tree can be disastrous; a lightning strike will move down the tree to ground. From the ground around the tree, current flows through the earth and will flow through objects on the earth. In addition, side flashes will occur to a person or other object in proximity to the tree or object receiving the strike. Amperage values for these strikes range between 5 kA to 200 kA, with voltages in the millions. The strike lasts about 100 μsec. The damage to a person receiving a lightning strike may include: burns at the point of entry, internal lesions, skeletal fractures from falls or muscle contractions, neurologic damage, paralysis, muscle pain, photophobia of intense light, internal abdominal bleeding, cerebral cortical splitting, and subarachnoid hemorrhage (Critchley 1934; Silversides 1964).

When lightning strikes a building, the current flow moves to ground over lines of smallest resistance. The grounding of power circuits within the building results in this current shunting to ground, provided the building is grounded according to code specifications. Without proper grounding of the electrical circuits, the current flow will be essentially random, with side flashes to conductive elements within the structure. Because devices are connected to the electrical circuits, some of this current or even side flashes can appear in or on the electrical apparatus. One of the authors (W.A.G.) of this chapter experienced a lightning strike event. During his service in the Army, he was housed in an old wooden barracks. A thunderstorm occurred and moved directly over the barracks. Lightning struck the building (or nearby) and appeared in the latrine. Side flashes were observed between water pipes in the latrine, accompanied by loud cracking sounds. These strikes and side flashes occurred approximately three times before the storm moved on. This building was not properly grounded! Protection against lightning for buildings, equipment, and personnel was discussed at some length by Bernstein (1991b), to which the interested reader is referred for a comprehensive examination of details and further references. You should shut down and disconnect participants from any apparatus if you are in a building that does not have adequate lightning protection when a storm occurs. Temporary and older buildings may be vulnerable.

**Current Limits**

The 50–60-Hz frequency has cost advantages for the transmission of power. Unfortunately, this range of frequencies generates the maximal physiological response. Underwriters Laboratories (1990), in advising the Consumer Product Safety Commission, recommended current limits for electrical apparatus. The values were taken from the work of several investigators and are set so as to be applicable to persons with the lowest thresholds. Because of large individual differences, the threshold current values are higher in many persons for a given effect. In general, children have the lowest values, women have intermediate values and men have the highest values. Sweeney (1992) developed a physiological model to explain these age and gender differences. The limits for the startle reaction and let-go are based largely on the work of Dalziel and Mansfield (1950) and Dalziel and Massoglia (1956). The limit for ventricular fibrillation is based on work reported by Ferris and associates (1936), Kourvenhoven (1949), and Geddes and Baker (1971).

**ELECTRICAL CHECKLIST**

It is helpful to have a checklist for evaluating the electrical safety of the laboratory. We have compiled the list below from our own experience and several other sources. Sources are identified unless it is our personal recommendation.

1. Metal ladders must be legibly marked “CAUTION — Do Not Use Around Electrical Equipment — Severe Shock Danger” or an equivalent warning (OSHA 1996).

2. All cord-connected portable electrically operated tools must be effectively grounded or have approved double insulation (OSHA 1996).

3. All non–current-carrying metal parts of electrically operated tools and equipment must be effectively grounded (OSHA 1996).

4. Every six months, routine maintenance should be performed on all electrical devices in the laboratory. Checks should be carried out on grounding connections, current leakages, and electrical cords. Current leakages are best detected by qualified biomedical personnel. A local hospital or your engineering department should be contacted for advice (Moak 1994).

5. Have laboratory personnel report any hazards associated with electrical equipment or power-carrying cords (OSHA 1996).

6. Each time an electrical apparatus is used, inspect the grounding and the GFCI.

7. When service to electrical apparatus is necessary, switches must be opened, locked out, and tagged — if