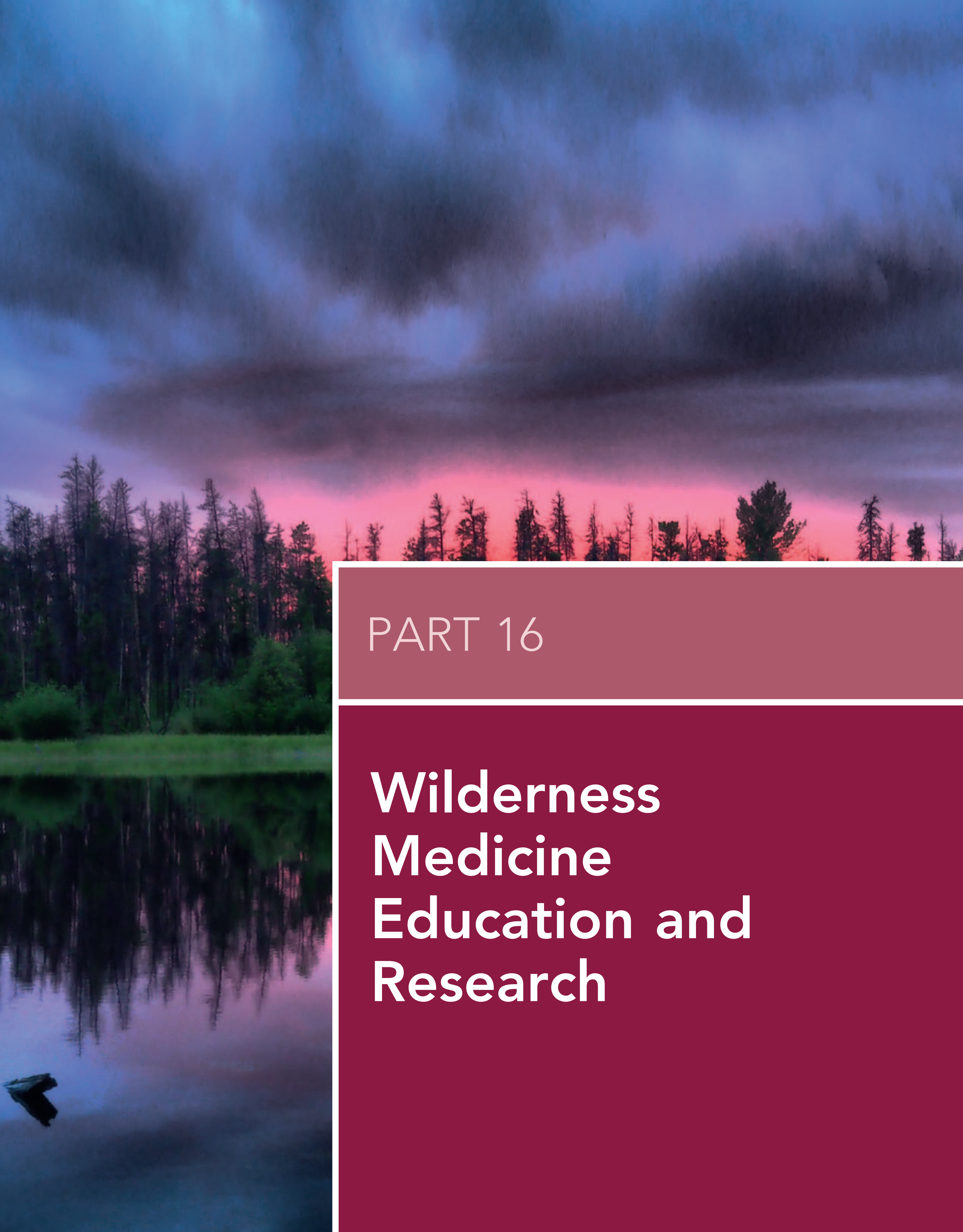

PART 16

Wilderness Medicine Education and Research

CHAPTER 113

Wilderness Medicine Education

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Whether the learner is an outdoor recreationalist or a physician specializing in one or more subdisciplines of wilderness medicine, wilderness medicine education has become increasingly popular and accessible. The features of wilderness medicine that make it attractive to an increasing number of people also present unique challenges to development of its educational programs. Training options and venues vary widely, from lecture sessions at conferences to fellowship programs lasting several years, and from first-aid courses for laypersons to semester-length programs combining wilderness, medical, and rescue curricula. The need for special attention to the learning process in the discipline of wilderness medicine has been recognized since the early 1990s; there are a growing number of collaborative efforts to define the core curriculum content and ensure the quality of the educational experience.[4,5,24,83] Work has been done at the individual program level to incorporate modern concepts of adult education in health care; however, little has been written about best practices and strategies for training wilderness medicine educators and designing training programs. There are no universally accepted standards for delivery of education or assessment of outcomes unique to this discipline.

The spectrum of learners in wilderness medicine is broad and diverse and closely mirrors the types of experiences to which the discipline applies. On one end of the spectrum are laypersons who seek to acquire knowledge on basic first aid, sometimes related to foreign travel, for reasons of safety or security. This group includes outdoors educators, guides, and outfitters who have not been medically trained. Next are persons seeking formal search and rescue medical training, including conventional emergency medical technician (EMT) and paramedic training tailored to the wilderness setting. The next level is represented by expeditionary advisors and multiple types of emergency care providers (e.g., EMTs, nurses, and physicians) who practice in isolated circumstances. Finally, there are technically oriented researchers and other professionals who seek topic- or environment-specific experience and fellowship with others who share their level of interest (Figure 113-1).

Early work by the Wilderness Medical Society (WMS) noted the differences between wilderness and urban prehospital emergency care.[120] These differences clearly illustrate what makes wilderness medicine education unique.

- Harsh environments greatly influence decisions on treatment and resourcing (Figure 113-2).
- There is a close link between basic survival needs and clinical care.
- Prolonged evacuation transport times of patients to definitive care are common.
- Uncommonly encountered injuries and clinical syndromes are seen because of exposure to extreme environments.
- Common illnesses and injuries require different approaches when complicated by austere circumstances.
- Advanced medical techniques may be required because of the nature of an injury or illness or prolonged transport times.
- Often, no immediate or reliable remote contact with a controlling physician in a definitive care setting is available.
- The need for improvisation of equipment and creative problem solving is typical.
- Expectations for successful management of a serious injury or illness are tempered by the circumstances.
- Standard urban protocols may be unrealistic or hazardous to caregivers.

Evolution of traditional models of adult education in health care has had a positive impact. These models incorporate widely varied teaching techniques that stimulate adults to learn difficult material at the deepest levels. Wilderness medicine challenges these models to deliver even more. The diverse nature of both teachers and learners adds another dimension. Traditional medical education tends to foster development of individualistic attitudes and may not produce practitioners who easily serve the needs of a group. However, successful management of situations that arise in the wilderness may hinge upon the ability of participants to serve as subordinate members of a team. Many wilderness medicine skills are not easy to learn and retain. They are technically difficult but also may need to be recalled immediately and applied accurately under adverse conditions with limited resources. Training often does not closely approximate the true impact of extreme surroundings on emergency or urgent care rendered in the wild.

As with any skill set, wilderness medicine techniques are best learned and maintained in the environments in which they will be applied. Wilderness medicine practitioners are typically action-oriented professionals who prefer to learn and practice their craft in the outdoors. Relying primarily on training in harsh environments may make it difficult to reliably deliver a high-quality learning experience that results in formation of lasting knowledge, however. In the field, absence of resources and presence of adverse conditions may limit the ability of advanced providers to use and maintain advanced skills. For example, physicians may well find themselves performing the same first aid, applying the same splints, and using the same hypothermia treatment as the lay provider, predominantly because resources are constrained (Figure 113-3).

This highlights the need to separate preparation and conditioning for the environment from education in order to facilitate the learning process.[4] Logistics and varying skill and physical conditioning levels of learners make it unreasonable to carry out full practical exercises for every wilderness medicine topic in every venue at which they are taught. As a result, most wilderness medicine programs combine traditional models of teaching (e.g., lecture format) with various types of experiential or event-based techniques.

Health care education generally serves independent groups that are homogeneous in their levels of education and learning experience. Groups such as nursing, medical, EMT, and physician assistant students have their own educational programs. Their professional preparation is generally addressed using subsets of educational techniques with little cross-pollination. Once a health care worker is fully certified in his or her field, the worker carries these differences forth as he or she becomes a learner and/or teacher in the continuing medical education/continuing education unit (CME/CEU) setting. It is from this educational melting pot that wilderness medicine draws its teachers.

In wilderness medicine, mixing groups (e.g., different specialties) of learners is inevitable. The groups represent different learning styles and all levels of health care certification and experience. In any given wilderness medicine educational program, one can find participants from most physician specialties seated next to EMTs of all levels and applications. Nursing vocations are well represented, as are PhD researchers, health care administrators, and laypeople with focused interests. Into this mix are thrown basic students from all health care vocations.

FIGURE 113-1 Wilderness medicine scenarios help learners of varied backgrounds function together in small teams. *(Courtesy Shana Tarter.)*

Finally, the growing international attention given to wilderness medicine as an academic discipline adds another factor. This mix of learners and blending of practical skills creates an interesting and often educationally enriching dynamic. In no other area of health care is the educational challenge at the same time so exciting and daunting.

Compounding the challenge of diverse learners are the varied educational backgrounds and teaching styles of the wilderness medicine educators. The process that prepares someone for a career as a leading academic pulmonary researcher produces different cognitive and practical skills than do mountaineering and scuba diving. The skill set required to effectively teach any of those highly technical wilderness medicine fields is different. The logistics of career management and available time make blending all desirable attributes and skills into the consummate wilderness medicine educator a rare event. This leads to a pool of educators whose teaching credentials might largely be derived from practical experience or notoriety rather than from having acquired specific training in planning and delivering adult education.

Instructors who provide wilderness medicine training should have a foundation in learning theory and skill at facilitating various elements of the learning process. It is unfortunate that although effective educators are instrumental in training practitioners, most practitioners are never formally trained as educators. Many persons who teach wilderness medicine do so because of their passion, but are without specific training or demonstrated competence as educators. The leap from providing patient care to teaching others to provide patient care can be significant. Excellence in a clinical field does not necessarily translate to excellence as a clinical teacher.

FIGURE 113-2 Wilderness medicine is a discipline practiced and learned in and around the extremes of environment. *(Courtesy Fred Baty.)*

FIGURE 113-3 Wilderness medicine helps all providers focus on strong basic life support skills. *(Courtesy Melissa Gray.)*

One might presume that the high levels of education attained by individuals in these groups of learners would make the wilderness medicine educator's job easier. Except for the truly passive attendees to whom effective learning is less important than are the setting and experience, this proves not to be the case. Learners' expectations for receiving exciting, well-taught education are high, and they hold educators accountable. The well-prepared educator should have studied and understood the nature of a learner, just as an actor should be familiar with an audience.

Despite numerous adult education theories and the large amount of published work in this area, especially in disciplines of health care, there remains relatively little that specifically addresses wilderness medicine. Anecdotes, common sense, and the educational bias of the teacher are more common than hard evidence to support the preference of any education theory or its application over any other in this unique discipline. It is a general assumption that established techniques are of great use in wilderness medicine education. However, there remain two fundamental challenges. The first is determining which techniques work best for specific circumstances and how to apply them with specific types of learners. The second is preparing a cadre of wilderness medicine educators who are formally trained to understand the process and to make these applications work. Finally, as innovations, such as "digital health," accrue, wilderness medicine educators may find themselves among the first to determine their effectiveness.

PRINCIPLES OF ADULT LEARNING

There are important differences between the education of children and adults. These differences go far beyond the need for adults to be directive of their own learning and for children to be directed. Because of their general clientele, the details of the various learning theories may not be as important to wilderness medicine educators as an appreciation of some of their fundamental concepts. Although most wilderness medicine education is delivered to adult learners, the keen observer may note similarities to the education of school-age children. This speaks to the importance of attending to fundamental concepts. Much of the discipline is focused on acquiring skills meant to be used in emergency or urgent situations. These skills are most effectively taught by applying basic educational models.

Adult learning is generally predicated upon motivation. In the case of wilderness medicine, this might be personal enrichment, a professional opportunity, satisfying a job requirement, or an interesting continuing education experience. It may be that the learner is motivated by a previous experience for which the learner seeks validation of her or his actions or information that will allow the learner to perform more confidently in the future.

Regardless, the adult learner will generally present with a foundation of information and life experience that can at times be an impediment to assimilating new information. Adults tend to give greater credence to things they learned initially and are hesitant to reform their beliefs. Therefore, educators must create a safe opportunity for learners to explore their beliefs while coaching them toward a new understanding. Without developing this trust, students may remain resistant to learning.

BASIC PRINCIPLES

Some basic steadfast principles exist throughout modern academic thinking on adult education. The concept of proximity means that learning is enhanced and mastery achieved when new information or skills are used immediately. Classroom lectures in wilderness medicine are often necessary but are less effective with regard to proximity than are hands-on and small-group seminars.

Learners generally prefer educational approaches that focus on concepts and principles instead of fact-based information.[119] A concept derived from the teachings of Sir William Osler and known by nearly every classically trained physician holds that one should never spend time memorizing facts from a book at the expense of hands-on patient contact. This is why problem- and scenario-based learning has been incorporated into most modern health care education programs. The nuances of problem solving cannot easily be garnered from a book. Precious learning occurs at the bedside. Reading is important, but cannot replace education that takes place in "real life."

Learners respond favorably when they are able to participate in developing their own learning objectives.[119] The negotiation process between student and teacher that leads to properly established objectives builds relationships and trust that are at the foundation of the adult learning process. Participation by learners in goal setting facilitates ownership of the process and leads to higher levels of performance. Allowing this form of collaboration may seem counterintuitive to some, especially to educators used to teaching children, because they may use a more directive style of teaching.

Feedback to students may be the most important ingredient in solidifying learning and completing the education cycle.[119] To be effective, this should be direct, specific, and individualized to each learner. There are many reasons why this may not occur in health care education, ranging from the simple logistics of managing large classes to fear of retribution from students in the form of harsh evaluations if they feel they have been unduly criticized. However, these are not likely concerns in wilderness medicine education, because the typical program lends itself well to supporting a balanced learning experience. It also provides an opportunity to help students learn new study habits and improve skills performance. These habits transfer readily to learning other disciplines.

CONCEPTS, THEORIES, AND MODELS

There are numerous models to draw upon when developing an educational experience appropriate for the adult learner. One model seeks to balance the cognitive, emotional, and social needs of learners. Adult learners identify closely with the cognitive elements of learning, such as skills, knowledge, and understanding. To be more effective, the cognitive elements must be balanced with the emotional and social elements of the experience. Learner receptiveness is increased when the learning experience is enjoyable and respectful of diverse opinions. When the learner feels acknowledged, he or she will be more willing to participate, communicate, and cooperate. By balancing all three elements of an educational experience, the educator improves the opportunity for new learning to replace preconceptions.[56]

The Education Cycle

The notion that broad concepts of the process of learning can be applied as a cycle has been utilized in wilderness medicine education while planning a mountain medicine curriculum.[94] As depicted in Figure 113-4, the program director first makes an assessment of the needs of the learners, getting to know the audience. Next is the often-underestimated task of establishing tailored and focused learning objectives. The educator then selects teaching methods and settings that best accomplish the objectives while meeting needs and expectations of the learners. Finally, after the experience, the educator makes an assessment to ascertain whether learning has occurred. This final step may be the most difficult and least attended. These elements will be addressed later in this chapter.

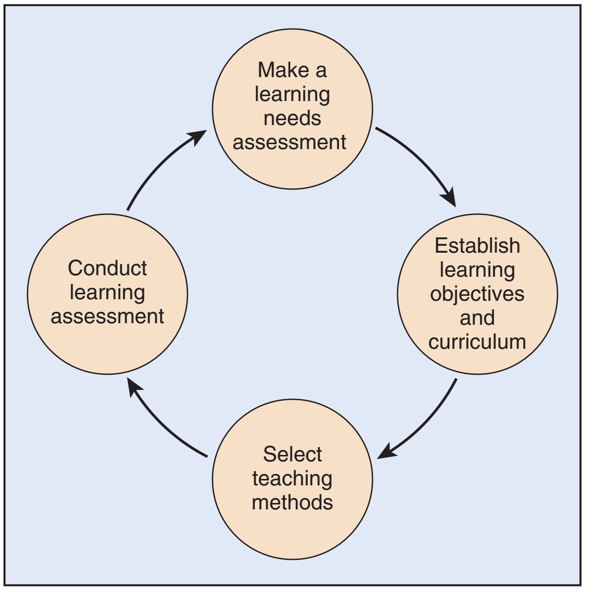

FIGURE 113-4 The education cycle.

Experience-Based Learning

Kolb's model of learning is based on how individuals internalize and process learning experiences. Learners perform an action, referred to as a "concrete experience."[58] Then, they process the new information by "reflective observation." Next, they consider how the new information can be applied to their unique circumstances by using "abstract conceptualization." Having internalized the experience, they attempt it by "actively experimenting" with what they have learned to apply the knowledge and/or skills in new and unique ways. This model is reflected in several of the teaching and assessment techniques discussed later, especially those that address concrete skills.

Education and the Human Organism

Setting the conditions for learning can be conceptualized by using Maslow's famous explanation of how humans address fundamental needs.[74] Vella's work in popular education extends these ideas to the realm of education in the social context, but still deals with rudimentary human nature.[113,115]

Unmet physiologic needs, such as warmth and hunger, tend to impair learning because humans prioritize toward survival. Unfulfilled security needs, which Vella refers to as safety, distract from any process that does not pose such an immediate threat. In adult education, safety issues may be subtle.[113] Students who do not feel free to voice opinions or reveal a deficiency may be considered to lack a safe learning environment. Identification with a group of learners addresses the need for belonging that is used by organized team sports and the military. The need for self-esteem may be met by recognition for academic achievement in front of one's peers. Finally, the highest level of Maslow's concept, self-actualization, is represented by satisfied expectations on the part of the learner. By expanding these concepts and directly addressing each in the classic hierarchical fashion, an educator can remove many obstacles to learning during the planning phase of the educational experience. A learning event that accounts for them will have a high likelihood of success and have an impact on the student's life well beyond the experience.

Learner Sophistication

Another powerful tool available to teachers is identification of the level of understanding, or "sophistication," of the learner. Neal Whitman proposed four levels that learners traverse as they acquire new knowledge and skills. Correctly matching teaching methods to these will improve the overall experience by saving time, and increase the likelihood of fully meeting expectations.[119]

Most people begin the education journey at the level of being "unconsciously incompetent" and do not know enough about the material to know what they do not know. They become "consciously incompetent" as they gain appreciation for the amount and nature of the information they need to master. Next, they become "consciously competent," in that they know how to perform the skill or can use the information, but not yet with efficiency or at the level of mastery. The final stage, that of the teacher, is becoming "unconsciously competent." At this level, the learner becomes so practiced at the skill and the understanding is so well internalized that it can be performed to standard without consciously focusing on the process. The learner simply knows what to do.

Principles of Andragogy

There have been numerous efforts to roll learning theories together into a concise package of tools for health care education. To this end, the work of Malcolm Knowles is widely read and often cited by education academics. He put structure to the concept of helping adults learn and called it "andragogy." He suggested that through the principles of andragogy, adult learners are most successful when they are assisted in the process rather than directed through it unassisted.[55] Knowles made five basic assumptions about adult learners from which he derived his principles. They can be summarized as follows: (1) Adults tend to have internally and not externally focused motivations for learning; (2) the learning process should be related to solving real-life problems; (3) existing knowledge and experience greatly influence learning; (4) self-direction improves the learning experience; and (5) adults learn best with problem-based rather than subject-based methods. Knowles's seven principles of andragogy are summarized in Box 113-1.

Learner-Centered Education

Jane Vella has applied learning theory in unique ways to the social context across different cultures. She recognized that education lay at the heart of many social issues. The teacher's message is often lost in the delivery because of avoidable cross-cultural and interpersonal obstacles. She maintains that the key to adult learning is clear dialogue between the teacher and learner.[113,114] Educators too often fail to establish productive dialogue and hence select ineffective teaching approaches. Vella suggested that traditional hierarchical teacher-student roles be discouraged. Teachers should become facilitators. Barriers to dialogue are "addressed and eradicated." She offered to popular education a paradigm that places the learner at the center of the educational universe. Her principles link theory to practical use in a way that enables learning in challenging circumstances. Vella's principles are summarized in Box 113-2.

BOX 113-1 Summary of Knowles' Principles of Andragogy

- The proper learning climate sets the stage for success.
- Adults prefer to actively participate in and contribute to planning for methods and curricula.
- Adults respond well to self-diagnosis of learning needs.
- Adults prefer to self-determine learning goals and objectives.
- Allow adults to identify their own resources for learning and formulate plans for their use.
- It is better to support adults while they implement their own learning strategies, rather than direct them through the process.
- Encourage reflective self-critique in the learning process.

BOX 113-2 Summary of Learner-Centered Principles

- Perform a learning needs assessment.
- Provide for learners' safety.
- Develop sound relationships to foster trust and encourage dialogue.
- Properly sequence learning tasks from simple to complex, and solo to groups.
- Provide opportunity for praxis—performing learning tasks and reflecting on the experience.
- Respect each learner's life, circumstances, autonomy, ideas, opinions, and time.
- Attend to ideas and feelings; link actions to them.
- Provide for immediate application of new skills and knowledge.
- Make dialogue more accessible by clarifying roles and reinforcing equity between teacher and learner.
- Use teamwork to enhance education.
- Engage learners directly by using small groups and an open exchange of ideas.
- Teachers and learners are accountable for what is learned. Learning must be tangible and observable.

Learning-Oriented Teaching Model

Cate and associates proposed their notion of a model of teaching based on concepts from educational psychology.[14] Their proposals are meant to influence all aspects of adult education, especially those of curriculum design, teaching techniques, and teacher assessment. An attractive feature is a method to "inventory" and match teaching and learning styles to improve outcomes. The authors build a model around what they identify as the "components of learning" and the "amount of guidance" that learners require to navigate the experience. Their premise is that, because education seeks to enable people to "function independently," the process should foster self-regulation of learning. In the model, learners mature from "externally guided" learning through "shared guidance" to self-guided or "internally guided" learning. This applies to both cognitive (what to learn) and affective (why to learn) components of learning.

Decision Making and Error

Wilderness medicine offers educators a controlled opportunity to help students look at how they make decisions and what traps or errors plague them in the process. By asking students to consider not only what decision they made, but also how they came to that decision, the educator can provide another tool to help develop the students' clinical reasoning skills. Able practitioners are expected to make appropriate decisions but commonly are not provided the tools to analyze their decision-making processes. Thus, they are less likely to be able to train others in the same skill.[17] Helping students recognize functional strategies and tools to avoid errors will create greater awareness for them in the future.

People make hundreds of decisions every day, most with little thought or consequence. These decisions may involve a small amount of research, or another opinion may be sought before making a choice. However, this sort of unstructured approach applied to wilderness medicine decision making can create problems for both caregivers and patients. Even small decisions, such as whether a treatment for wound infection appears to be efficacious, can have significant consequences if the infection becomes too difficult to manage in the wilderness and there is a missed opportunity for a simple evacuation. The distance from assistance and having to live with the consequences of a decision in an austere setting are important factors that inform wilderness medicine education.

In the wilderness, practitioners must make choices in environmentally challenging situations with incomplete information in the absence of external support or resources. Nevertheless, there are predictable methods by which practitioners make decisions. The experience and ability to recognize patterns helps with perceptual decision making; protocols and analysis contribute to logical decision making. A skilled practitioner will engage all of these to a greater or lesser extent while making even a single decision, all the while remaining vigilant about potential errors and traps.

Experience is an important part of one's ability to recognize patterns and see similarities and differences between patients. The greater one's experience, the more one is able to develop a sense of typical and atypical presentations. Persons with limited experience may confuse experience with expertise, and even the experienced practitioner can make perceptual errors. Brains seek patterns. When a caregiver notices recognizable elements in a patient, it is possible to quickly anchor on a diagnosis that is not adjusted even when contradictory information becomes available.[36] Though objectivity is espoused, practitioners may seek evidence to support a conclusion rather than purposely trying to disprove it, which is known as confirmation bias. Decisions may be unduly biased by stress or emotion. Unconscious anxiety felt by the wilderness medicine provider when caring for a patient while thunderstorm clouds build, or the emotional connection to a recent patient with a similar presentation, can affect choices. Although a practitioner may have had significant experience managing a certain type of patient, if prior experience has all been in the controlled clinical setting, the stress of being in a remote setting may certainly influence decision making. How to manage this situation must somehow be taught to future wilderness medicine practitioners. Similar education missions are shared by the military, search and rescue professionals, ski patrollers, and expedition doctors.

To help sift through the overload of information that health care providers must manage, providers rely on heuristics or simple rules of thumb. For instance, if a patient has increased heart and respiratory rates and pale, cool, and clammy skin, a state of physiologic shock is suggested. Novice practitioners find heuristic shortcuts to diagnosis and treatment particularly useful when beginning to build a base of experience. However, heuristics can certainly be oversimplistic, situational, and sometimes incorrect. They can be applied quickly and might allow someone's initial thoughts and actions to focus in the right direction, but they carry the challenge of sometimes causing caregivers to cease thinking, investigating, and analyzing a given situation.

Another tool that is quite helpful is the protocol. One inherent challenge of providing wilderness medicine training to non–health care professionals is the inability for them to develop a solid patient care experience base prior to making challenging medical decisions in remote places. Even health care professionals may not be accustomed to making evacuation decisions. Protocols can help bridge the gap between training and experience. They also relieve the practitioner of relying on memory for many small details that can be easily looked up. Written guidelines covering the specifics of treatment, medication administration, and evacuation decisions help simplify complex situations. No set of protocols can cover every possible situation, but they can be a reasonable substitute for prompt access to expert opinion.

Finally, decisions can be made based on a studied analysis of the situation. In the clinical setting, this might involve using a variety of laboratory tests, as well as imaging and consultation. In the wilderness, the primary tool is patient assessment. Thorough, thoughtful, and careful assessment helps ensure that the provider makes rational decisions. Comprehensive assessment takes more time than does a general impression or applying a heuristic, but time is often available in the wilderness setting. The emphasis on ensuring that every patient receives a complete physical examination and determination of a full set of vital signs, and yields a thorough history, is one of the hallmarks of wilderness medicine training. When students take shortcuts through this process, a well-prepared educator will remind them that by doing so they are dangerously prone to making assumptions and denying themselves access to valuable information.

The strongest decision making balances the objectively observed with the subjectively perceived. It is important to become mindful students and practitioners of the process. This self-awareness can help avoid consequential errors. Throughout the process, caregivers should prompt themselves to consider: What assumptions am I making? Am I missing or ignoring data that do not fit my pattern? What are the most likely and worst case scenarios? Have I considered alternative diagnoses? What emotions are influencing my thinking? Have I discussed my thinking with someone else? Have I sought input from my team? Have I used my protocols, checklists, and other resources? Can I step away from the situation to minimize my emotional connection and thereby create an objective space in which to think? After the situation is resolved, providers should reflect on each experience, assimilate learning, and seek feedback from others. If one cannot articulate how a decision was reached, one should strive to improve this skill.

BOX 113-3 Kaufman's Principles to Guide Teaching Practice

- The learner should be an active contributor to the process.
- Learning should relate to understanding and solving real-life problems.
- Learners' knowledge and experience are critical and must be accounted for.
- Learners should have the opportunity to self-direct their learning.
- Learners should have ample opportunity to practice, self-assess, and receive constructive feedback.
- Learners should have frequent opportunities to reflect upon the learning process.
- Role models have a great impact on learning.

Putting It All Together

Theories and models are meaningless without practical application. Direct extrapolation of ideas from theorists who have diverse backgrounds and agendas to the realm of wilderness medicine education is difficult. Kaufman reviewed several adult education theories in the context of health care education.[54] He examined them for key areas of commonality and offered simple principles to "guide" medical educators as they think about and plan educational experiences (Box 113-3). Wilderness medicine educators can easily adopt these.

EDUCATIONAL TECHNIQUES

There are a myriad of delivery techniques available to the modern medical educator. Although techniques have been extensively studied across many disciplines, the method of educating the medical learner in a way that results in consistently improved performance and outcomes exceeding other methods remains elusive. There is no single method that is effective for all types of learners in all settings. In wilderness medicine, this is compounded by the degree to which hands-on skills depend on a solid grasp of basic science combined with flexible application of clinical medicine.

Selection of the most effective methods depends largely on the setting and the expectations and needs of learners. The prudent curriculum designer avoids incorporating attractive methods of presentation designed to capture attention without substantively improving educational quality. Schweinfurth characterized the problem of finding the right mix of techniques when he described his use of interactive training among otolaryngology residents. He referenced comments from a focus group of trainees, discussing what he called "innovative learning strategies." He found that learners were hesitant to endorse innovative strategies, in order to avoid complex exercises that might compromise the limited time available to conduct didactic sessions. His learners found some attempts at innovation to be "too experimental" or a "waste of time."[101] The lesson should be that innovation, as an end in and of itself, may not serve the learner. Innovation that causes the learner to walk away with a sense of improvement can be considered successful.

Learning Strategies

Current literature on successful learning indicates that most students lack knowledge about helpful study strategies.[11] Traditional reliance on rereading material or repeated practice of a single skill, also known as massed practice, creates the illusion of knowledge. The familiarity that comes from reading material for the second or third time or the short-term improvement noted with repetition may be illusory and lead to overconfidence. Numerous studies show such short-term improvements do not last. Instead, learners need to build new study habits, which include self-testing, spacing and interleaving of material, and struggle. These strategies may feel less productive initially, but result in greater retention and application of knowledge.

Learners may engage in self-testing or retrieval practice by quizzing or being quizzed on previous material. Educators can facilitate this process through regular short quizzes, with scenarios requiring students to apply information learned at an earlier point. In-class exercises force students to recall information and compare and contrast it with similar information, and create structure for students to test each other. These strategies may create initial discomfort for the learner; however, the evidence is clear that learning will be deeper. When applied to clinical performance, both written testing and use of standardized patient experiences produced superior results on final written examinations compared with rereading and reviewing material. The students who trained with standardized patients performed better on final patient examinations than did those who trained solely by written testing.[62] This research underscores the important role that scenarios and simulation training play in wilderness medicine, as opposed to exclusive reliance on lectures and reading materials.

There is strong support for the concept of spacing or interleaving information by introducing new material before the individual has achieved mastery of the original content. The educator can apply spacing in the structure of skills practice. Rather than repeated practice of the same skill, consider multiple shorter practices throughout the educational experience. Students may gain initial experience with a specific skill and then later be asked to reproduce that skill in scenarios or other forms of practical assessment. This allows the student the opportunity to "forget" between experiences. The struggle to perform, sometimes called a desirable difficulty, strengthens the student's learning.[11] The educator can apply the concept of interleaving by consistently introducing new concepts and crafting scenarios that draw upon a mix of topics. Students may be challenged to consider solutions to problems they have yet to encounter. Using a scenario to introduce a new topic provides the opportunity for a student to apply problem-solving skills in the absence of preexisting knowledge. Even if the solution is initially incorrect, the student will demonstrate improved understanding when the topic is formally introduced.[11]

In addition to misperceptions about effective study strategies, most learners and educators still hold to the belief that receiving information in one's preferred individual learning style has a bearing on the quality of learning. The learning styles theory is well entrenched in education at all levels. There are myriad resources available to assess individual learning styles and prepare teachers to provide instruction for specific types of learners. Many learners will claim to know their preferred learning style and hold firmly to the belief that they will fail as learners unless provided instruction in a matching format. However, research does not uphold this belief. Learners misconstrue satisfaction with performance. What seems clear is the importance of matching the topic to the delivery method. When the instructional style is closely matched to the material, all learners perform better, regardless of their perceived learning style preference.[11,90]

Research also shows that learners who have the aptitude for building mental models out of general concepts, known as high-structure learners, are more capable of assimilating information than are low-structure learners, who rely on examples.[11] Educators can support high-structure learning by teaching in principles rather than absolutes. Students have a higher likelihood of successful problem solving when they can rely on decision-making principles or skills principles rather than single examples. For instance, teaching a student principles of a good wilderness splint (padded, not bulky, rigid, adjustable, digits accessible for assessment, joints above and below a fractured bone immobilized, bone above and below an injured joint immobilized) allows the student to problem solve with different materials regardless of the environment. Teaching the student to build one splint with specific tools may inadvertently restrict the student's ability to adapt when he or she is lacking those specific materials. The educator can facilitate the student's ability to recognize commonalities by highlighting and repeating patterns between topics. This will help the student to more quickly sift through information to improve the focus of the student's assessment and continue to enrich mental models as the knowledge base grows.

The adage "less is more" has a firm place in the world of education. Learners are frequently inundated with both volume and detail. Many are challenged to decode the underlying message buried in the mountain of information. Without understanding the fundamental and most critical concepts, it is unlikely that the recipient will apply information appropriately to solve a problem. Though the learner certainly bears some responsibility for this process, the educator must also be clear with the messaging. To this end, educators should consider applying a simple process to distill each topic into its fundamental essence before delivering the information (Box 113-4).

BOX 113-4 Example of Three-Sentence Class on Diabetes

Although diabetes is a complex disease process, the educator can practice simplifying information to help novice practitioners make decisions in remote settings.

1. Diabetes is a disease that affects the body's ability to process sugar.
2. Diabetics can become ill when they have too much or too little sugar.
3. If a known diabetic has a change in mental status, give sugar and evacuate.

One approach is to teach a topic with three informative, yet simple, sentences. The sentences should reflect the underlying principles to be conveyed. This is a remarkably difficult activity until one practices and develops the skill. This exercise provides a valuable framework for lectures, practice sessions, and scenario debriefings. It also creates a structure for quizzing students to assess learning. It is easy to dismiss the idea of simplification as unsuitable to medical education. Yet, this seemingly rudimentary activity often highlights a lack of understanding of material on the part of the practitioner turned educator. Persons who excel at clinical education understand the power of making complex things simple. By modeling this with students, they provide an example of how students will ultimately communicate with patients.[99]

Lecture

Lecture is the most often used educational technique and is the default medium for most educators. This structured approach to information delivery feels familiar to both student and teacher. It offers several important advantages. Large amounts of information can be delivered in relatively short periods of time. Planning is generally easier for the lecture format. It requires little logistical support and only one teacher. It works well for highly technical information that the learner will most likely have to study again in order to internalize. Lectures can be easily enhanced with audiovisual aids. All of this adds up to a degree of efficiency that is highly attractive to the resource-limited educator. In one small but interesting study, Reed illustrated that, despite the availability of highly technical and resource-intensive teaching methods, a simple "low-cost, low-tech" lecture approach can offer rewards in terms of improved skill performance.[98]

The lecture technique has several equally important disadvantages. Learning is highly dependent on the delivery skill of the teacher. Because of the passive role played by the learner, many adults do not respond as well to this approach. It is generally

BOX 113-5 Methods to Enhance a Lecture

- Clearly communicate the purpose of the lecture to learners.
- Be familiar with the culture, attitudes, expectations, professions, and experiences of learners.
- Pace the lecture; use the 12- to 20-minute rule for the span of attention. Break up the pace with discussions, a question-and-answer period, or group work.
- Personalize the presentation with examples.
- Speak from notes rather than complete scripts. Know the material!
- Use visual aids.
- Use critical incidents with which the learners are familiar to make teaching points and solidify learning.
- Leave with a question or challenge to encourage learners to explore further.
- Perform self-assessment through videos, learner evaluations, and other forms of appraisal.

accepted that levels of retention of material presented by pure lecture are lower than more active teaching techniques.[106] There is generally a limited opportunity for hands-on applications and practice. Thus, the usefulness of lectures is limited in some areas of wilderness medicine that are largely skills oriented. The more restricted the opportunity for student questioning and dialogue, the less effective becomes this technique. Students can often more effectively learn information to be presented by lecture by themselves, particularly when they are able to view the material in a supportive setting. Methods to enhance the lecture are listed in Box 113-5.

Length and depth of a lecture are dictated by both time limitations of the class and experience of the student group. They may also be influenced by expectations regarding prereading or study. Regardless, when planning a lecture for a wilderness medicine topic, teachers may find that using a simple five-section outline structure can be helpful. Beginning with the definition of the injury or illness, the teacher then provides background information relevant to the audience. For example, for the topic of cardiac chest pain, the wilderness first-aid student may only need to hear that "Chest pain can have many causes ranging from sore muscles to a heart attack. Two prominent causes are angina (heart pain) and heart attack (myocardial infarction)."

Learners may next be taught to recognize the condition. Typically, a description of signs and symptoms and supporting imagery works well for this purpose. Unless the goal is to teach clinical management of environmentally induced emergencies, one should consider how a condition can be realistically assessed in a wilderness setting rather than relying on information that will likely only be available in a traditional clinical setting. This can be followed by description and demonstration of wilderness treatments, accompanied by discussion of evacuation criteria for the injury or illness. It is helpful to distinguish between criteria for an evacuation (requiring medical care, but not an immediate threat to life or limb) and a rapid evacuation (threat to life or limb). The final step may be to consider relevant prevention strategies. This lecture flow will help students apply the information and make real-world decisions.

Although lecturing may feel like a straightforward skill, there are common pitfalls to be avoided. Instructors are responsible for creating a safe learning environment for students. Pertinent to lecturing, this is strongly associated with language choice. Profanity, judgmental descriptions of patients, use of only one gender pronoun, impatience with student questions, and inappropriate commentary generally undermine the educator's credibility and foster an environment where students are reluctant to ask questions. Rarely do instructors recognize when they are making off-putting comments, making self-awareness difficult. Another seemingly innocent tool that can be misapplied is the anecdote or story. The educator's intent may be to illustrate a teaching point. However, if learners perceive that the focus of the effort has become the teacher rather than the teaching, or if the story deviates from the message, it becomes a distraction. The choice to include an anecdote or a story should be scrutinized with the same level of intentionality as is every other element of the teaching process.

Preparedness and familiarity with the topic are of critical importance. Memorization of material is minimally effective. The first few times that an instructor teaches a topic, some form of notes may be helpful for staying on task and tracking small details. Students will appreciate the use of notes if they support the flow of the lecture and the accuracy of its content; they will dislike the use of notes if they become a distraction, however. The lecturer is on a slippery slope if he or she reads the notes or slides to the class instead of engaging the class with eye contact and using audiovisual support tools primarily to enrich the lecture.

The desire to address the learning need at the moment or the fear of loss of credibility if the instructor is unable to answer a question can tempt the instructor to deliver incorrect or unhelpful information. Educators should be prepared to acknowledge the limitations of personal knowledge by answering "I don't know" to questions, with a commitment to follow up and obtain the answer for the student. This creates a sense of trust.

Time is an insidious factor that creeps into an instructor's vocabulary while teaching. Seemingly innocuous references to time can devalue the quality of the lecture. Phrases such as "We'll go quickly because we're running behind," "Let's skip the demo because I'm over time," "Take a quick 5-minute break," "Let's talk about that later so we can finish," or "Let's finish early so we can all get out of here" imply disorganization and poor time management on the part of the instructor and the instructor's assumption that the participants have little interest in learning. Students are in a course to learn and in many cases have paid for the privilege. An instructor owes it to students to provide as much education as possible in the allotted time window. An instructor's monologue about time and whether the class is ahead of or behind schedule should remain internal. Students are often oblivious to the small increments of time allotted to various topics. They tend to be concerned more with starting and ending the training day at the specified hours, and remaining true to the time allotted for breaks. By referencing time, students will become conscious of it. If the instructor does not reference time, the students will remain focused on the experience at hand and will not be influenced by instructor anxiety.

Finally, instructors must be attentive to all subtle nuances of professionalism. From attire to confidence with operation of the audiovisual equipment to management of the group, the instructor's educational competence will in part be judged by the little things done or not done.

Demonstration

It is challenging to take a skill that is commonplace and familiar and demonstrate it in a manner that is successfully reproducible at a high degree of quality by others. Educators are quickly enticed by the temptation to lapse into jargon-laced vocabulary and a presumption of knowledge and experience not appropriate for the audience. For example, by using technical terms or phrases such as "You all know how to tie a surgeon's knot," the educator may establish credibility or perhaps display prowess but in the process alienate learners who cannot tie the knot and now feel they are not welcomed into the elite circle of those who know how to tie it.

Demonstration of a skill(s) providing a particular type of care in a traditional clinical setting may not translate well to an effective presentation in a wilderness setting. Teachers must commit to the same high level, and perhaps more, of preparation when designing and practicing demonstrations as they do in crafting lecture notes and slides. Poorly executed, incomplete, or nonreproducible demonstrations that are visible by only a portion of the class are often the result of overestimating how familiar learners are with the skill. The goal of a demonstration is to create a final visual image for learners that serves as an enduring model.

To avoid demonstration pitfalls, the wilderness medicine educator can employ a few simple strategies. Although a frequent goal of wilderness medicine education is to train providers to improvise, the instructor should not improvise in order to complete a demonstration. Forethought when planning a demonstration may include such details as choosing individuals best suited to the task and making the teaching point, while also considering how best to be certain that the task can be successfully accomplished. When teaching how to turn (logroll) a patient as a single rescuer, one may select the largest individual in the group to serve as the patient in order to make the point that the skill is about mechanics and not strength, but also select a "rescuer" of sufficient strength to be able to turn the patient. If one is building a lower extremity splint, an individual with a fairly cylindrical leg may be chosen as the patient, rather than one with bulging thighs and skinny calves, to simplify splint construction. For an intravenous demonstration, one may select a student with easily located veins. Students will adapt their knowledge to real people and difficult situations, but the instructor's demonstration should be well performed and successful. Another factor is choosing the correct equipment. The instructor must ensure that demonstration gear is appropriately sized and in good working condition. For example, effectiveness of an otherwise good demonstration can be diminished by using a short sleeping bag to demonstrate a hypothermia wrap on a tall person. Considering the position of the demonstration patient and the instructor in relation to the class will maximize visibility and enhance learning. Students may be asked to leave their seats to come close and observe. They may find overuse of "pearls of wisdom" and discussion during the demonstration to be distracting. Minimizing distractions will focus students' attention on the skill being taught. The successful educator can often teach by showing without telling. Some skills lend themselves to a completely silent demonstration. Finally, practicing the demonstration in advance with the materials that will be used during the demonstration will avoid a cumbersome presentation in front of students and increase efficiency. Time is often limited, so the shorter the demonstration, the more time students will have to practice the skill, ask relevant questions, and receive answers.

Skills Development Sessions

One attraction of wilderness medicine is its skills-rich content. Focus on improvisation provides ample opportunity for practicing techniques such as splint building, lifts and rolls, and wound closure. These practice sessions provide an opportunity for students to adapt and apply principles learned during lectures and demonstrations while receiving feedback and coaching. However, skills demonstrations notoriously have the opportunity to go astray if they are not carefully designed, planned, and performed.

Consideration should be given to appropriately matching the type of practice session to the topic. Some skills have a series of steps that should be practiced in sequence; certain assessments and cardiopulmonary resuscitation fall into this category. Some form of guided practice would be well suited for early practice with these topics. An instructor can lead a group in a step-by-step practice session, much like a square dance caller, to ensure that each student focuses on the task. Alternatively, students may guide each other through a series of steps using flow sheets or algorithms. As learners become more proficient with skills, they may become frustrated by this structure of practice, but it can be a helpful tool if it appears that learners are taking shortcuts in practice. The majority of skills-oriented learning tasks lend themselves to individual or small-group practice. If poorly managed, these opportunities can devolve into social time for students, who may see this as an opportunity to take care of unrelated needs. Inappropriately sized or poorly maintained equipment may force students to verbalize skills rather than practice them. To avoid this, establish strategies in advance to keep people focused on a task. Considerations include the group size, length of practice, types and operation of equipment, and practice outcomes. Teachers can facilitate the setup of instruction and transitions by dividing large groups into small practice groups, providing an ample supply of preapproved equipment, and briefing groups on what other materials they may use. Instructors should state the time limit for the session and indicate how many turns of practice of each particular skill

FIGURE 113-5 Practicing skills in a controlled environment builds confidence before learners apply the information in more challenging environments. *(Courtesy Gates Richards.)*

are expected for each student, and whether an instructor needs to assess the performance in some manner. Student performance during practice sessions often directly reflects the quality of demonstration provided to students. When watching students practice, it quickly becomes apparent when they fail to complete an element of the skill, usually because the instructor did not teach that element and, rather, finished the demonstration by verbalizing how the technique "should" be completed. The instructor must be present and engaged during practice sessions, which provide an excellent opportunity for individual evaluation and coaching (Figure 113-5).

Problem-Based Learning

A highly effective trend in health care education is using problem-based learning (PBL). PBL can take various forms, but generally learners are presented with a problem and guided through a structured discussion that leads to a preestablished solution. This learner-centered approach has proven popular among students and demonstrates comparable outcomes when compared with other, more traditional formats. An interesting aspect of PBL is that student-led experiences tend to be more highly favored among participants than those facilitated by faculty, yet the outcomes remain at least comparable in terms of satisfaction and examination scores.[41,104]

PBL offers great versatility to the curriculum planner. It can be used whether the focus is on acquiring pure fact-based knowledge or practical skills. It is most often applied in the small-group setting and therefore may pose logistics challenges in certain space- and resource-limited settings. It complements the strengths of small-group learning in that it reinforces communication and problem-solving skills, teamwork, individual responsibility for learning, and the need to share knowledge.[122] PBL tends to yield the best results when it is structured and forces learners to use critical thinking skills. It fosters the process of analysis, organized problem solving, and decision making, using group discussion to direct and reinforce learning. The general format for PBL is presented in Box 113-6.[7]

Case-Based Learning

Case-based learning is a subtype of PBL that is extremely useful in wilderness medicine education. It makes use of several powerful aspects of theory to solidify learning. This method improves outcomes over pure lecture for certain types of material. Many of the skills-oriented topics in wilderness medicine can be easily presented through scenarios and cases. The teacher can easily modify case scenarios to suit various learner levels, styles, and objectives. It can be modified for learning experiences in the field setting because, if properly planned, it requires minimal logistics support.

BOX 113-6 Steps of Problem-Based Learning

1. Presentation and evaluation of the problem
2. Generation of solutions to the problem (hypotheses)
3. Inquiry to review the hypothesis, including gathering information, such as laboratory tests and findings of a physical examination
4. Interview information
5. Application of the information gathered to the original problem
6. Review and synthesis of what has been learned and evaluation of the process

This technique motivates learners because it relates directly to the reasons for which they sought the experience. It offers an automatic sequence and information source for presentation, because cases flow in accordance with actual or simulated events. The teacher generally facilitates discussion and assists students with understanding and methods to organize information. Clinical problem-solving styles can easily be demonstrated.

Scenarios and Role-Play

Scenario-based, role-play training is quite familiar to most if not all prehospital emergency care educators. It maximizes many of the strengths of newer approaches to adult education because it guides self-motivated students through a process of "discovery" of the information.[70] The main role for teachers in this format is to facilitate, not direct, the learning process.[43] Being an expert in the clinical details of each case is less important than understanding how to apply PBL. This method is often scripted and makes use of actors, props, and moulage to simulate real-life situations. The logistics of carrying out this aggressive training technique may be prohibitive to some programs, but the investment is worth the effort in terms of retention of knowledge and improved outcomes shown by learners. Nearly all organizations that train prehospital wilderness medicine practitioners use some form of complex case- or scenario-based learning program. Role-play has benefits beyond the teaching and development of technical skills, notably including communication. Introduction of role-play as a training method may enhance the realism of technical skills training and lead to better patient-provider communication.[86]

Scenario- or simulation-based training is a popular choice for reinforcing assessment skills and providing opportunities for error in a low-risk environment. Learning will not occur simply by providing this type of experience, so whether using people in role-play or simulation mannequins for the scenario, it is crucial to design the experience with carefully crafted goals (Figure 113-6).

FIGURE 113-6 Role-play scenarios are an effective tool for reinforcing assessment skills and introducing decision making. *(Courtesy Marcio Paes Barreto.)*

Role-play has benefits beyond teaching and learning technical skills. One recent randomized controlled trial confirmed the utility of using role-play when teaching communication skills. The authors of this study of medical students randomized to learn a skill with and without role-play concluded that, although there were no differences in technical performance between groups, introduction of role-play as a training method enhanced the realism of technical skills training and led to better patient-physician communication.[86]

Similar to practice sessions, scenario training should have established parameters that include time limits, an appropriate ratio of rescuers to patients, and allowable equipment. It should be both realistic and targeted to the audience. Because the topic is wilderness medicine, it follows that scenarios should teach, assess, and reinforce care delivered under austere and remote wilderness conditions. Although plane crashes and motor vehicle wrecks certainly occur during wilderness trips and are relevant for certain response entities, they do not represent the core of wilderness injuries and illnesses. Scenarios used early in an educational program should be straightforward and focus on reinforcing correct and consistent skill performance. This is generally accomplished by allowing only one or two rescuers per patient. As the education process progresses, scenarios can evolve in complexity and severity. Ending the program with a scenario celebrating the competent performance of basic skills sends students off with a memory they may find useful when they have to perform in the real world.

The following template is a helpful tool in developing successful scenarios. Note that the "story" is intentionally left as the final element. This focuses the developer on the goals of the experience and allows for the scenario to be used regardless of audience, location, or environmental challenges. By changing the story, the scenario can be made relevant to many audiences (Figure 113-7).

Scenario Template:
Three learning objectives or debriefing points
Ratio of rescuers to patients
Equipment needed
Time limit
Moulage (stage makeup for injuries) needed
Patient briefing, including the story, mechanism of injury or illness, injuries and associated symptoms, vital signs, acting cues, physical location boundaries

FIGURE 113-7 Wilderness medicine scenarios can be readily adapted to specific settings, such as marine operations. *(Courtesy Shana Tarter.)*

Rescuer briefing, including the story, location, time of day, resources, patient information, scenario goals or end point, performance expectations

Scenarios can be used to reinforce a previous topic or to introduce a new topic. It is simplest to set up many iterations of the same scenario, for example, five patients all with exactly the same condition and each rescue group manages the same situation. This facilitates simple, targeted debriefings. At times, it may be appropriate to set up a scenario to illustrate a differential diagnosis. For instance, some patients might exhibit a mild form of injury or illness, and others a severe form. In the debriefing, the instructor may highlight the differences and emphasize the implications for care. In multicasualty incident scenarios, each patient may have different injuries. Each level of variability adds preparation time, which runs the risk of taking away from student practice time.

Realism is a critical element of scenario-based training. Rescuers and patients should be coached to stay in their roles to create an emotional engagement with the experience. Patients may need a specific script to understand how to accurately portray learning objectives. Both underacting and overacting can be detrimental to the learning experience. Stage makeup, or moulage, can be incorporated to great effect. Having students play the roles of both rescuer and patient provides opportunity to gain experience applying new skills, as well as opportunity to provide feedback to others about those same skills (Figure 113-8).

Student safety is a priority. In scenarios, limiting the geographic distribution of students and ensuring there are adequate rescuers to manage each patient are ways to mitigate risk. Monitoring assessments, including the appropriateness of physical contact and language usage, are also important requirements.

Instructors or evaluators actively engage with the students during each scenario by watching their performance, correcting errors, and asking questions. When students are new to the skills, teaching and feedback are more directive. As they progress, students are prompted to consider their decision making or asked how their treatment meets or deviates from the key principles presented in a particular class.

It is common for students to see scenarios as problems that have a specific answer. After they believe they know the answer, they may cease their assessment and assume they are finished. The instructor can reinforce the importance of a complete assessment in a number of ways. Using moulage may help to create multiple injuries for students to find. If all major areas of the skin are visualized, discovering a simulated injury serves as a reward for a thorough physical examination. Scenarios may be designed with causal factors that can only be illuminated through a thorough interview and that are unlikely to be found early in the assessment. Simulated patients are told that rescuers must actually assess vitals each time; only after they are verbalized should any modifications be stated. Students can hold each other accountable for incomplete assessments.

FIGURE 113-8 Moulage adds to the realism and the intensity of scenario-based training. *(Courtesy Shana Tarter.)*

Effective scenario debriefing is what helps solidify an experience into learning. Ultimately, a well-crafted debriefing session may illustrate the pitfalls of taking shortcuts to a diagnosis. As noted above, debriefing points should be the backbone of scenario construction. Two or three points of emphasis are generally appropriate for most scenarios. Considerations for debriefing points might include:

Does this patient need evacuation? Quickly or slowly? By what means?

Was this patient improving or deteriorating? How did you know?

Give a patient report as if you were making a cell phone call.

What principles did you apply in your treatment?

Was there a mechanism for a spinal injury?

What are your anticipated problems?

The debriefing should be structured and time efficient. A debriefing that is lengthy or generates multiple student questions may be indicative of poorly designed scenario outcomes or a scenario that was too complex.

Subject-Based Learning

The term *subject-based learning* (SBL) is a euphemism for traditional teacher-centered techniques of presenting information. The student in an SBL setting is the passive recipient of instruction rather than an active participant in the learning process. SBL methods typically present information on a broad topic in a format mainly based on lecturing. Health care curricula designed around SBL tend to be redundant, because broad topics may deal with the same or similar types of information. For example, a traditional first-year-of-medical-school, basic science curriculum will have a series of lectures on pharmacology, biochemistry, pathology, and microanatomy. Each will incorporate specific material on diabetes presented by different departments. The student may have to wait a year for a session focusing on diabetes that incorporates elements of pharmacology, biochemistry, pathology, and microanatomy.

Although SBL has a role, most health care educators have incorporated more learner-centered techniques, such as PBL, into their curricula. The main drawback of SBL is that by favoring efficient delivery and lengthy, complex curricula, it often fails to take advantage of features in adult learning theory that are known to lead to higher rates of retention and deeper learning.

Discussion

The technique of discussion is a versatile and highly effective teaching tool rooted in behavioral science. People learn better when information is presented in ways that challenge them to process it in more than one way. Although not as efficient as a lecture in terms of the quantity of information that can be delivered, it offers advantages to the wilderness medicine educator when teaching problem-solving skills and broad concepts that can be applied to many types of scenarios. Students more readily internalize material that they have to intellectually manipulate in various ways. The information is introduced, processed, and discussed. Students modify their own notions and then formulate solutions based on their new internal constructs of the problem. Learning is guided by the facilitator-teacher and reinforced by the students, all of whom are going through the same process and adopting a similar problem-solving skill set.

There are two basic modes of discussion-based learning.[60] The Socratic questioning method challenges students to identify the most important features of a specific problem and then reconstruct it using general principles that are the true focus of the discussion. Developmental discussion approaches the problem in parts. It keeps all students focused on one part at a time and takes advantage of the group setting to ensure that teaching points are addressed.

Teacher-facilitators may highlight discussion with the powerful tools of analogy, discovery, and induction to stimulate learning and ensure retention.[22] The process of analogy illustrates concepts by asking students to use examples with which they are already familiar. The process of discovery leads students through a sequence of steps from the most basic to the more complex. This guides them to the final goal of deeper understanding of the principal learning objective. The process of induction asks students to take general lessons from specific examples or experiences, make comparisons, and draw new conclusions relevant to the learning objective. These three techniques can be applied in any setting that involves learner interaction with the teacher.

Small-Group Learning

Selection of a teaching method is highly influenced by the class size and quantity of information that must be learned. Large classes that must digest substantial amounts of information tend to push the faculty into selecting passive modes of teaching. The traditional CME conference at which hundreds of attendees review highly technical material is an example of this. Passive, lecture-based methods are not the most effective and often not the most efficient for all types of learning, especially in wilderness medicine. It is now widely accepted that skills-based learning presented in a small-group setting is a better way to teach practical skills.[64]

The problems inherent in teaching large groups can often be overcome by adopting a combined approach. In this strategy, the information is delivered in part to the entire group. Learners are then broken into small groups to conduct activities that allow them to discuss information, use information, and solidify learning. Within a small group, there is usually a more favorable teacher-to-learner ratio and greater self-direction of learning.

Wilderness medicine offers ample opportunity to use the combined approach or the pure small-group venue for teaching. Both rely upon the process and mechanics of group experiences. The simple act of breaking a large group into smaller groups does not constitute small-group teaching. This method requires the educator to possess skill and experience with group processes in order to avoid pitfalls that detract from learning. When done well, small-group learners take away solid lessons and the strong relationships that they had to build to learn them. However, if the teaching is done poorly, learners walk away dissatisfied with negative attitudes toward learning, the setting, and the discipline.

To understand group learning is to understand how individuals within the group interact. Bruce Tuckman's original concept of the developmental sequence of small groups should greatly influence how teachers plan and conduct these activities.[35,52,110,111] The general strategy for teachers is to become familiar with the stages, recognize their manifestations, and use a planned approach that gradually releases control of the teaching process to the group as members become more able to direct their own learning.

During the *forming stage,* group members get acquainted and become oriented to the setting. Student anxiety may hinder learning as interpersonal dynamics take shape. Students tend to adopt a passive mode of learning. They respond best during this stage to a more directive teaching style with clearly defined expectations and structured events.

During the *storming stage,* the group's identity begins to take shape among some members, while others continue to pursue individual goals over those of the group. Dissent may be voiced about leader- or teacher-directed tasks. Teachers should demonstrate strong but patient leadership to move through this stage without alienating group members. They should openly encourage support for group-generated goals.

During the *norming stage,* the group identity solidifies. Individual ownership of group goals and a greater affinity for teamwork are hallmarks. As they gain a sense of safety, members who interact with other participants display genuineness. Leadership tasks should be directed to group members. Learning activities, such as role-play and case discussions, become most useful.

During the *performing stage,* the teacher acts only as a resource for the group, which has developed to a point of relative autonomy. The group is able to plan and conduct its own activities, as well as make self-assessments in an organized and productive fashion. Energy is spent on learning rather than on the interpersonal mechanics of the process.

The role of the teacher in a small-group setting should be oriented toward facilitation of learning rather than direct delivery of material. However, the teacher remains accountable and cannot take a completely hands-off approach and expect that objectives will be met. By attending to the details of process, the teacher ensures that the learners do not have to perform this task. The teacher creates the proper learning environment and keeps the process on track. Some common mistakes made by small-group "facilitators" include reverting to lecturing on the part of the teacher; a teacher who talks too much; students who do not participate unless prompted to do so or directly questioned; students who lack preparation for a session; students who are overbearing and domineering; and students who want to be provided with a quick and simple solution to a problem rather than engage in the process of group discovery.[49]

Despite not being part of the learner group, the teacher has great influence over the process and the outcomes. A poorly prepared teacher who ignores the internal dynamics of the group positions the experience for failure. Techniques available to avoid these problems include having agreed-upon rules for the conduct of sessions; having clearly stated tasks and objectives; using the rhetorical method of questioning to stimulate thinking; taking a lengthy pause after posing a question, allowing students to answer; not offering immediate solutions or guidance unless participants appear to be taking the wrong path; attending to body language and mannerisms of all participants, both when they are speaking and when they are listening; and addressing the entire group, rather than a single student, with mannerisms and eye contact.[49]

The general steps in preparing for and conducting small-group teaching are summarized in this way:

Establish the objectives or outcomes of the activity. What should the students be able to do?
Select the specific tasks and methods to achieve the desired outcomes (e.g., case presentation with discussion, or group project and presentation).
Choose appropriate facilitators and faculty.
Select and modify the environment and group size; make group assignments.
Prepare and coordinate for training support materials.
Familiarize oneself with the individuals and dynamics of the group; identify potential problems early.
Conduct the activity; modify techniques as required to address the unique needs of each group.
Assess learning; retrain as needed.
Assess methods, and modify them as needed for the next session or course.

Small-group learning is a rewarding and highly effective method of teaching. It requires preparation and experience. The characteristics of small-group learning make it the teaching method of choice for many wilderness medicine educational activities, especially when combined with techniques such as simulation, scenarios, and case presentations.

Distance Learning

Since the explosion of Internet-based applications has occurred, distance learning, traditionally provided via correspondence courses, has taken an entirely new direction. More people than ever find it possible to further their education without physically entering the classroom. Although web-based distance learning has found widespread application in many academic areas, it is a little-used tool in wilderness medicine education. It is not yet conducive to experiential education.

Recently, organizations have begun to offer hybrid wilderness medicine certification programs that include online prework and study paired with shorter-duration in-person training programs. This course model may be popular for students with limited availability away from their regular endeavors, but is not yet available on a large scale. Inadequate research exists to demonstrate whether students perform on par with those that spend a longer time immersed in in-person training.

The Internet offers many advantages for medical educators. Courses that are not offered as complete web-based packages can be supported by Internet applications such as email, distribution of materials, enrollment, needs assessments, and testing. To these can be added videoconferencing, discussion boards, live topic-specific chat rooms, and presentation of live events via video streaming. Nearly any software application that can be used on a home computer can be offered in some fashion over the Internet. With the advent of high-speed connectivity and constantly changing security programs, obstacles to efficiency and learner security have been minimized. Virtual learning environment software enables all of these applications to be managed efficiently while keeping the focus on the learner and not the technology.[45] The ability to hyperlink from any web page or digital document quickly brings an entire world of information to the learner.

For all of its attractiveness, the Internet is not a panacea for wilderness medicine education. There are two main disadvantages. First is the need for learners to possess sufficient computing power to allow rapid and efficient downloading and presentation of course materials. This is made worse when they travel to remote locations. It is worth recognizing that while online or hybrid learning may afford tremendous flexibility for students, it requires significant dedication to technology development and acquisition, oversight, and administrative support. Large organizations that offer this approach find it necessary to hire full-time support staff to provide a comprehensive and reliable product. Many wilderness medicine educators find it difficult to dedicate the resources necessary to bring it to full implementation. However, even small organizations find great usefulness in some applications.

For many wilderness medicine topics, passive approaches to learning, such as distance learning online, suffice to deliver information. It is up to the student to embrace the style and internalize the material. Basic science and clinical topics that can also be taught in a lecture format with audiovisual aids work well when presented online. However, much of the body of wilderness medicine knowledge, especially that dealing with the prehospital phase of care, is largely experiential and requires direct interaction with other people.

There are numerous ways that education can be delivered online. Broad categories include pure distance learning and the hybrid web-based course. In a completely web-based program, all course work, materials, sessions, and assessments are transmitted via the Internet; even assistance from teachers occurs by email or live message applications. This method is a true virtual learning experience. Alternatively, many organizations offer hybrid online courses in which students use Internet applications as an additional tool to complete portions of a course while they are also required to participate in periodic face-to-face sessions.

Many health care practitioners involve themselves in wilderness medicine because of the fellowship with other uniquely qualified and experienced professionals. As web-based applications become more widely used in wilderness medicine, educators will be increasingly challenged to ensure that learners do not feel isolated from their wilderness medicine peers and role models. The learner, not the technology, must remain at the center of the effort. Internet applications must be selected for how they enhance the learning experience, not merely for the sake of using a new technology.

Field Experiences

Medical schools and residencies have followed the lead of commercial wilderness prehospital emergency care (WPHEC) programs in moving learners out of the classroom and into the field.[70] Rotations and electives that include field training experiences of various lengths are now highly sought. These have the effect of maintaining high levels of student interest and satisfaction. They offer direct relevance and immediate application of newly learned skills. When coupled with an effective group process and feedback, the benefits of field training make this a powerful venue for skills-oriented education. These experiences are most often part of a curriculum that incorporates other techniques, such as lecturing and PBL, in a didactic setting (Figure 113-9).

Concerns include the safety and security of participants and liability issues for the sponsoring organization. The logistic support package can be expensive and complex. The quality of the experience is greatly influenced by uncontrollable factors, such as climate and weather. Proper screening and selection of participants are critical to success, especially in programs conducted in remote locations or physically demanding environments. Multiple techniques, such as scenarios and hands-on practical exercise, can be applied simultaneously to maximize the learning experience. Field training affords an opportunity to introduce nonmedical skills, such as leadership, wilderness survival, and land navigation.[70] This not only generates interest but also creates well-prepared learners and an overall lower level of risk.

OUTCOMES AND COMPETENCY-BASED EDUCATION

The notion that one should be able to demonstrate that a given intervention or technique will result in measurable, reproducible, and predictable outcomes is woven into the fabric of the scientific and business culture. Not surprisingly, in medicine, it is now taken for granted that recommended interventions are based on a body of evidence that shows improved reliability and safety. However, the seemingly fundamental ideas that data and evidence should drive educational program development and delivery and that programs should measure and be accountable for their outcomes (e.g., how their students perform) are relatively new to health care education. Successful programs determine specifically what they want their students to know or be able to demonstrate (competencies). They collect and assess data on the effectiveness of their teaching methods and then use that information to generate continual program improvements.

Over time, teaching programs across the spectrum of disciplines in health care education have adapted traditional teaching methods to a more modern approach using outcomes and competency-based principles. Most wilderness medicine programs have also adapted. For example, programs that offer

FIGURE 113-9 Learning conducted in the field under genuine conditions is a vital component of any comprehensive wilderness medicine course. This method enhances skills development for individuals and teams and facilitates several aspects of the 360-degree evaluation of learners. *(Courtesy Fred Baty.)*

medical school or graduate-level residency elective experiences that are approved by a parent academic institution may be required to demonstrate that curricula use measurable, competency-based objectives. Teaching methods and instruments used to evaluate learners who seek academic credit from parent institutions may be required to use competency-based formatting. Fortunately, most wilderness medicine educational programs incorporate fundamental concepts of adult education and have required only modest changes to curricula, training methods, and assessment tools. Many wilderness medicine programs do not require extensive modification with respect to outcomes-based education. Those that wish to satisfy specific compliance requirements generally use multiple and overlapping methods to assess learners and outcomes data to enable them to demonstrate continuous improvement in the educational program. Competency-based assessment tools are widely available on the Internet and can be modified for almost any wilderness medicine educational setting. When evaluating curricula and processes for competency-based improvements, programs may consider three areas: (1) Do learners achieve the established learning objectives? (2) Can the program demonstrate this with evidence? (3) How does the program demonstrate continuous improvement in its educational process?

ASSESSING LEARNERS' NEEDS

Performing proper assessment of the needs of students before designing a curriculum leads to a fulfilling experience for all. Jane Vella claims that this critical step is necessary to "truly honor the time investment of the learner and create the conditions for meaningful dialogue between learner and teacher."[113] People whose motivations for learning are ignored "quickly become bored and indifferent." They often walk away from the experience dissatisfied or without completing the program. A wilderness medicine course planner may query potential learners or other organizational stakeholders about their goals in attending an educational program. Organizations, such as camps and outdoor education programs, may be asked about the specific skills they want their staff members to master. Some examples of information the educational planner may wish to obtain are:

1. Why do the students want to spend their valuable time learning this material?
2. What are the levels of training and vocation of the group?
3. Are any specific outcomes more important than others to the group?
4. What is the relevance of the wilderness medicine learning experience to them?
   - Job requirement
   - Prerequisite for another course
   - Enhancement of recreational activities
   - Preparation for emergencies
   - Acquiring knowledge for safer exotic travel
   - Sharing fellowship with other wilderness medicine practitioners
   - Creative diversion
   - Academic advancement

Learner-centered education principles tell us that the needs assessment should lead to modification of course content or structure to suit the individualized needs of the learner. To become fully invested, students should be able to shape to some degree what will be taught to them. Thorough, individualized modification of curriculum content based on a formal needs assessment is likely to be impractical for certain standardized certification experiences, such as wilderness first responder (WFR) courses. Detailed needs assessments are seldom completed for wilderness medicine CME conferences due to the wide variety of learner types and motivations. Advance study of students' expectations and reasons for attending allows for more focused and tailored instructional events. The needs assessment can be easily accomplished with a questionnaire delivered by postal or electronic mail, telephone contact, or a face-to-face interview. The actual format is not as important as the mere act of soliciting input from students. Allowing them to actively dialogue about their learning will achieve buy-in. The curriculum design becomes overtly accountable to the students and results in much higher levels of internal motivation.

LEARNING OBJECTIVES

An area of wilderness medicine education that is often given cursory attention is that of providing well-constructed objectives for a course and for the individual learning activities contained therein. Most educators make an attempt, but well-written objectives are articulated too infrequently for the amount of education that is being delivered in the discipline.

Course objectives describe the overall purpose for students attending the course. They may include a job- or skill-related certification or simply enrichment skills and knowledge. They address what a participant should generally be able to do or know after completing the entire program. The objectives should be formalized, written, and distributed to anyone involved with curriculum design. They serve as a compass to guide all planning and design efforts. They also enable prospective participants to determine if the course is appropriate for them. For example, the objective of the wilderness first-aid course may be written as

"This course is intended to prepare the participant to perform basic first-aid procedures in locations where evacuations are primarily walk-outs or carry-outs with the assistance of local resources, and where local emergency medical services (EMS) access is expected in less than 8 hours. This is often in the context of short trips relatively close to assistance: day trips/camps, stationary wilderness camps, weekend family activities, and frontcountry outdoor recreation events."

Learning objectives are collections of words, pictures, or diagrams that tell others what the educator intends for learners to achieve.[64] Because they are designed for a specific activity or session, learning objectives should not be used as objectives or goals for an entire course. They are tailored to a single learning activity or a closely related group of activities; address preidentified needs and interests of the learner; are specific to levels and types of performance; are achievable, realistic, and time specific; and use verbs that specify behaviors that can easily be measured. When properly written, these objectives provide focus for individual instructors while preparing their offerings and guide selection of educational methods. Learning objectives establish outcomes rather than describe processes. The basic purpose of teaching is to facilitate learning in order to achieve measurable outcomes. A learning activity is a process designed to achieve a result. What students actually learn is the result and should be described in advance by objectives.[30]

A learning objective is constructed by describing an activity that elaborates specific knowledge or skills that a learner will be able to demonstrate following a successful learning activity. Well-written learning objectives are measured by written testing, observation, hands-on problem solving, or other methods of assessment. Words or phrases such as *know, think, appreciate, learn, comprehend, remember, perceive, understand, be aware of, be familiar with, have knowledge of,* and *grasp the significance of* are difficult to measure and are of little use when writing learning objectives in wilderness medicine. Examples of learning objectives that illustrate the concepts of being specific and measurable are as follows: The student will be able to …

…perform well during wilderness-setting role-play (not specific or measurable)

…carry an injured patient (specific; can be made more measurable)

…discriminate between edible and inedible wild plants (specific and measurable)

…feel more comfortable performing mass-casualty triage (neither specific nor measurable)

…express a point of view supported by valid evidence (specific and measurable)

Strong objectives, in addition to being performance based, specific, and measurable, are preceded by a condition statement to set the stage and aid with measurement specificity.[71] In writing objectives, answer the question: What should the participants be able to do and how well must they do it? Objectives must be

TABLE 113-1 Examples of Performance Verbs for Learning Objectives

Knowledge	Comprehension	Application	Analysis	Synthesis	Evaluation
Cite	Associate	Apply	Analyze	Arrange	Appraise
Count	Classify	Calculate	Appraise	Assemble	Assess
Define	Compare	Complete	Contrast	Collect	Choose
Draw	Compute	Demonstrate	Criticize	Compose	Critique
Identify	Contrast	Dramatize	Debate	Construct	Determine
Indicate	Describe	Employ	Detect	Create	Estimate
List	Differentiate	Examine	Diagram	Design	Evaluate
Name	Discuss	Illustrate	Differentiate	Detect	Judge
Point	Distinguish	Interpolate	Distinguish	Formulate	Measure
Read	Estimate	Interpret	Experiment	Generalize	Rank
Recite	Examine	Locate	Infer	Integrate	Rate
Recognize	Explain	Operate	Inspect	Manage	Recommend
Relate	Express	Order	Inventory	Organize	Revise
Repeat	Interpolate	Practice	Question	Plan	Score
Select	Interpret	Predict	Separate	Prepare	Select
State	Locate	Relate	Summarize	Produce	Test
Tabulate	Predict	Report		Propose	
Tell	Report	Restate			
Trace	Restate	Review			
Write	Review	Schedule			
	Translate	Sketch			
		Solve			
		Translate			
		Use			

clear and attainable. They are often constructed in an if … then sequence to facilitate clarity. Focus on acquisition or reinforcement of a specific element of knowledge or skill.[30] Style options for constructing objectives include the following:

Given X materials and within Y minutes, the student will build a Z device strong enough to support 25 pounds.

At the completion of this teaching activity, participants will be able to …

This last phrase is followed by a specific performance verb and the desired learning outcome. Examples of performance verbs are found in Table 113-1. The following is an example of a properly prepared set of objectives:

Aerospace Medicine Lecture: Fatigue, Desynchronosis, and Countermeasures
Time: 1200-1300
Speaker: Dr. Jane Doe
Lesson Objectives: At the conclusion of this activity the student will …

Summarize the results of studies on the effects of fatigue on air crews.

Give examples of the deleterious effects of fatigue on human performance and the accident rate.

Define desynchronosis and give examples of applications of its understanding to aviation medical personnel.

Outline various countermeasures that are available, as well as some, such as melatonin, that are currently undergoing investigation.

ASSESSING LEARNING

The last step in the education cycle (see Figure 113-4) is making a formal assessment of whether or not learning has occurred.[94] There are several reasons for testing in wilderness medicine education beyond the obvious need to validate and certify students. Learning assessment can be a valuable extension of the learning process. Kromann observed that "testing as a final activity in an in-hospital resuscitation skills course for medical students increased learning outcomes compared with spending an equal amount of time in practice."[59] Students seldom come away from a properly conducted and reviewed examination without having learned something. It can be said that this type of learning by assessment is the capstone of knowledge synthesis. Each examination completes the education cycle at a particular level and allows progression to the next with a higher degree of competence.

Learning assessments can be grouped for convenience into two general categories: formative and summative. Formative assessments are made before and throughout a course of instruction and have both learning and testing dimensions. Feedback after formative assessment is critical to shape additional learning. This type of assessment may take the form of a diagnostic examination to assess learners' needs and establish lesson objectives, or an intermediate examination to assess progress at a particular phase of training.

Summative assessments are generally used at the end of either a critical phase of training or course completion. This type of assessment is more often applied for certification and validation than as an extension of learning. Final course examinations and tests that lead to state or national certification in a vocation are examples of summative assessments.

TIMING OF EVALUATION

The learner uses feedback and information gained from formative evaluations to improve performance during the learning event or course. To be effective, formative evaluations must be provided to learners before the end of the training period. Although assessments rendered early in the training period allow more time for modifying performance, there may have been insufficient time for adequate and comprehensive assessment. Likewise, evaluation made later in the training period allows for more accurate and comprehensive assessment, but there may remain insufficient time for satisfactory remediation. Unless there are compelling reasons to render evaluations early (e.g., when questions of safety or impropriety arise), those provided to learners at the approximate midpoint of the training cycle tend to work well. These should be scheduled, anticipated by learners, and prepared and presented by faculty. Programs that use anonymous evaluation tools (e.g., at the end of a course) must collect and collate results from learners and faculty

FIGURE 113-10 Timely and specific feedback is especially important in the types of hands-on, scenario-based training frequently conducted in wilderness medicine courses. *(Courtesy Fred Baty.)*

and analyze the results. This may decrease usefulness of the instrument by causing a separation of results from the actual training event.[19]

FEEDBACK

Regardless of which tools a program incorporates into the overall assessment system, dedicated opportunities for immediate feedback on performance must be used to ensure maximal learning. The basic goals of feedback are to improve student performance and to strengthen learning. Although formative and summative evaluations that take into account numerous individual events capture performance over a given period of time, immediate feedback is needed to give learners the opportunity to make adjustments based on their performance during specific events or very brief and focused training periods. Learners that are not provided this type of feedback will be left to rely on happenstance to succeed at course objectives (Figure 113-10).

Limited feedback may come in the form of corrections on written tests or other assignments. However, the bulk of this feedback is likely to be associated with performance on skills and in practical exercises or scenarios. Feedback is especially important in these types of hands-on, scenario-based clinical training events that are frequently conducted during wilderness medicine courses. Hands-on skill training requires concrete demonstration of proficiency and does not rely on an evaluator who makes presumptions of a learner's thought processes to make an assessment. Properly conducted feedback makes an immediate connection between outcomes of learner actions and expectations as established by goals and objectives. This solidifies learning in ways that are impossible with other evaluation tools. However, the benefit decreases rapidly as time increases from the event to delivery of feedback. Feedback is effective when it is given immediately after an event by a person who has observed the event.[19]

Instructors who know the learning objective for the lesson know what to look for in student performance. They are able to watch students practice a skill and use their observations to check whether students are performing correctly. This ongoing assessment and feedback helps in the coaching of skills and serves as a check on the effectiveness of the instruction.

Instructors must create an environment where high-quality objective feedback is both expected and normalized. Recipients should understand that feedback is specifically targeted at helping them improve their performance, rather than being a personal attack. Properly conducted objective feedback should be delivered verbally and focus on the individual's performance or actions, rather than on character or intent. In other words, feedback should focus on the performance, not the performer. Instructors may be reluctant to provide critical feedback for fear of hurting someone's feelings or setting up an environment of conflict, yet without good coaching, a student's skills will not improve. In one study of medical students, half received constructive feedback on a specific skill and the other half received only general compliments. The performance of students who received feedback improved, whereas the students who received only general compliments showed no change in skill level. The students who received compliments showed significantly higher satisfaction ratings.[12] Instructors must work to build learning environments where feedback and coaching both improve performance and create satisfaction.

The ability to craft specific messages can improve student receptiveness. For instance, when evaluating the quality of an improvised lower extremity splint, one may choose descriptive comments. Rather than using general qualitative statements such as "That splint is poor" or "That would never hold up in an evacuation," the teacher may provide specific feedback to help the student evaluate errors and correct them. One may use a more direct and interactive approach, such as "Recall that immobilizing the joint above and below the injury is an important principle of splinting. How might you alter your splint to improve immobilization of the knee?" This provides specific direction for improvement without the feeling of qualitative judgment.

A common pitfall of providing feedback is for the instructor to impose a particular personal preference or style onto a student's performance. One of the benefits of principle-based teaching is that there are many ways to achieve the same goal. The improvisational nature of wilderness medicine is among its most attractive features to new learners. Students may find creative ways to achieve the principles of a particular skill that do not resonate with the instructor. Students will feel undermined if the instructor habitually corrects an appropriate performance not for accuracy but for stylistic preference. The instructor can offer enrichment to the student, but suggestions about alternative solutions should be crafted so as not to denigrate the student's choices.

In addition to feedback related to cognitive knowledge and skills performance, wilderness medicine educators have the opportunity to observe students' performance in group settings and leadership roles. Educators can take the opportunity to help students develop in both of these areas. Although it may seem more challenging to provide feedback about team performance, the instructor can still objectify comments to provide growth for students. As with individual feedback, general qualitative statements such as "Your incomplete information caused the incident commander to make a poor decision" may result in suboptimal group learning. A more specific, interactive approach more appropriately addresses the learning situation, for example, "Your plan was to perform a complete patient assessment. What factors caused you not to finish your assessment? How might you avoid this in the future?"

THE 360-DEGREE EVALUATION

As part of the new focus on outcomes-based education, many training programs provide objectives-based assessments of learner performance. In addition, programs often incorporate an assessment system that receives input from multiple evaluators. This is also called a 360-degree evaluation system.

The 360-degree evaluation accepts contributions to the development of learners from all types of people in the general sphere of his or her influence. It offers training programs a process by which numerous and varied perspectives may be used to more accurately assess all aspects of performance. It is presumed that observations of learners made from different perspectives are more valid than are traditional, more narrowly focused assessments. The usefulness of 360-degree evaluations in specific wilderness medicine training programs has not been thoroughly evaluated; specific instruments relevant to these settings have not

BOX 113-7 Examples of Components of a 360-Degree Evaluation

- *Global assessment:* Faculty provide an overall, comprehensive evaluation.
- *Peer assessment:* Other learners at a similar level of training provide an evaluation.
- *Self-assessment:* Learner provides an assessment of his or her own performance.
- *Ancillary staff assessment:* Staff, administrative, or nursing personnel provide assessments.
- *Patient assessment:* Patients may be asked to provide comments or complete surveys.
- *Performance metrics:* Assessment of the performance is metrics based (e.g., productivity, test scores, chart reviews, quality data, timed events).

been proposed. However, 360-degree evaluations that are widely available and validated within graduate medical education can easily be modified and incorporated. Usefulness of this method of learner evaluation depends on factors such as length of the course, contact with participants not taking the course (e.g., role-players and patients), and types of events used as training tools (e.g., small-group field-training events). A 360-degree evaluation may be found to be more relevant for courses that are longer, with more varied types of learner interactions over time (Box 113-7).

ASSESSMENT DESIGN

Two key concepts that should be understood when designing learning assessment tools for wilderness medicine courses are reliability and validity. These are applied separately when discussing written and skills-oriented testing.[49,103] They are particularly relevant to WPHEC courses, such as WFR or WEMT, which rely heavily on skills-based testing.

A reliable testing instrument consistently measures the desired outcome, no matter how many times it is administered. A host of factors influence reliability. The length of time it takes to complete a test, characteristics of the examinees, logistical and administrative problems, and variation in examiner methods act to decrease the reliability of an examination and mask the learners' true level of competence. One cannot address the validity of an assessment tool until reliability is achieved.

A valid testing instrument is one that measures what it was designed to measure. Simply put, it reveals the actual level of learner competence. Apart from reliability problems, issues that negatively influence validity include cases and scenarios that are not directly relevant to the learning objectives, poorly structured or improperly selected test questions, testing stations that do not adequately examine the skills that were taught, and failure to seek an expert review of course content during the design phase. The measure of validity is done in terms of examination scores. Having removed obstacles to reliability and validity (see Evaluating the Assessment Tool, later), the educator may use scores to make a direct link from teaching methods to achieving learning objectives.

The two main approaches to learning assessment in health care that are pertinent to wilderness medicine are written and skills-based testing. Apprentice-style one-on-one teaching with feedback is useful in other areas of health care education, such as primary nursing programs and physician training courses, but is often impractical for wilderness medicine teaching activities.

Written assessments are still widely used in health care education despite the growing application and demonstrated usefulness of progressive teaching techniques, such as hands-on skills development and PBL. The questioning format of written assessment may take many forms, but all formats generally test a student's reasoning ability and accumulation of knowledge as opposed to practical application.

Schuwirth and van der Vleuten[100a] proposed a list of criteria to compare the advantages and disadvantages of various types of written test formats and questions: reliability and validity, educational impact (how students learn the material to prepare for examinations), cost-effectiveness (expense in terms of money and time), and acceptability (how both students and teachers view the examination's effectiveness and relevance). To account for these factors, the most preferred method of developing written examinations is to use several types of test questions in each instrument. The types of examination questions that may be considered include true or false, single-best-answer multiple-choice, multiple true or false, short-answer fill-in-the-blank, essay, case-based key feature, and extended matching.

Skills-based assessment is particularly relevant in wilderness medicine education. It is the mainstay of competency testing for most prehospital courses. The two general subtypes of skills-based assessment used in wilderness medicine are skills subset testing (sessions focused on a single skill or a few closely related skills) and case- or scenario-based skills stations. Basic learning theory tells us that this popular testing method should be highly effective in achieving objectives and delivering highly retained learning. This bears out in practical application. There are two important disadvantages of skills-based assessments. First, the logistic requirements necessary to conduct high-quality testing can be burdensome. Second, examiners require a high degree of skill with regard to the testing process and mechanics to ensure the reliability and validity of results. The general steps in conducting a skills-based learning assessment session are as follows:

Decide if the activity is for practice, formative (intermediate) assessment, or summative (end-of-course) assessment. Inform the learners.
Match learning objectives to scenarios and/or cases in the examination.
Select satisfactory examiners and role-players; conduct thorough briefings.
Obtain logistics support, and prepare the environment.
Thoroughly brief the learners.
Conduct the assessment; check progress; modify as required.
Conduct an initial assessment of the instrument.
Review results with learners.
Conduct a thorough assessment of the instrument with broader comparisons.

Feedback can be formalized and documented in evaluations of student performance. These learning tools are more common in longer programs than in short conference workshops or layperson programs. Documenting student performance can consist of cognitive and practical test scoring. It may also expand beyond these objective measures to evaluations of the student's ability to lead and participate in groups, communicate, and perform in environments of uncertainty or adversity or the student's awareness of decision-making styles and techniques. These assessments flow from learning objectives. They should be based on assessment rubrics that can be communicated to the student to clarify standards for performance. These properly constructed rubrics can be effective tools for clarifying subjective assessments and expressing performance standards that may otherwise be difficult to comprehend.

For example, in addition to gaining wilderness medicine knowledge and skills, a program may have a learning objective that the students "effectively communicate patient information using the SOAP (*s*ubjective, *o*bjective, *a*ssessment, *p*lan) format. The evaluation then includes the criteria of "verbal SOAP reports." The grading rubric is described in Table 113-2.

Another example would assess the following learning objective: Identify the decision-making technique used in a scenario. The evaluation criteria could be written as, "identifies the decision-making technique used in a scenario." The grading rubric is described in Table 113-3.

Evaluating the Assessment Tool

Educators must evaluate their learning assessment tools to ensure reliability and validity. Simple methods may be used. For written

TABLE 113-2 Feedback Tool A

Expert	Competent	Novice	Beginner
Speaks clearly; well organized; concise and complete verbal SOAP reports	Speaks clearly; missing some minor data; followed general format of verbal SOAP reports	Difficult to follow flow of information; missing key data points; inconsistent quality of verbal SOAP reports	Ineffective verbal communicator; used inappropriate language

assessments, a review of examination scores and comparing them to attendance is a good first step. It should come as no surprise that students who do not attend specific sessions would do poorly on test questions designed to assess learning on that topic. If this level of analysis points to attendance problems, then there are other issues in the course, such as objectives, content, and quality of instruction, that should be addressed before the quality of the examination.

The process of test item analysis correlates the number of examinees that missed a given question with overall test scores.[21] This can be done on two levels. The first is within the group that was being tested at a given course. The second is over a period of time among several groups that took the same examination. As with any internal assessment tool, the latter style leads to stronger conclusions but takes longer to complete. Internal pattern analysis of test scores can reveal that either the instruction was poor or the test question not well written. The basic principle is that if a large percentage of students received a high score on an examination but a similarly large percentage missed a particular test item, then either construction of the item or the teaching method is likely at fault. This technique loses power and specificity at lower overall examination scores among those that missed the item(s) in question.

Skills-based learning assessments can be evaluated for quality using similarly simple analytic tools.[21] The attendance comparison mentioned above is an obvious starting point when reviewing individual performance.

Mechanics or logistics of the testing setting that seem irrelevant to the actual demonstration of knowledge and skills may affect test scores. An examiner who did not attend precourse briefings and is not familiar with what was taught, or worse, with what is expected, poses a problem. This can be revealed by noting a large percentage of examinees doing poorly at a given skill station despite doing well at other stations designed to test related skills. High-performing students that fail a particular station may be another warning sign. Testing stations that use role-playing with scenarios must account for the influence of the role-players. Poorly briefed actors that do not follow the script can make or break an otherwise competent learner.

Having made attendance comparisons and ruled out problems with the setting, examiners, and role-players, the problem if many students are doing poorly at a given skill station is most likely the quality of teaching. Retraining and retesting may be in order.

LIMITATIONS OF TRAINING

Training in all disciplines has limitations. It is impossible to supply an infinite amount of information to learners or to guarantee learning and retention of all material presented. Rather, the role of an effective training event is to provide a framework of knowledge for users to build upon through future experiences. For example, there are some themes and goals common to nearly all wilderness medicine prehospital care courses. Graduates should be able to respond to wilderness emergencies, perform thorough assessments with only rudimentary tools, provide treatment using largely improvised equipment, function in challenging environmental conditions, and make decisions regarding treatment and evacuation. For some learners, this requires adapting existing knowledge to a new and sometimes poorly understood environment. For others, this training is the sum total of their medical experience. Regardless of students' experience and educational background or where they begin in this progression, and regardless of the length of the training event, there are assumed limitations to this educational medium.

CONTRIVED SITUATIONS

Medical education is plagued by the challenge of training new providers to recognize the typical, yet be prepared to manage the atypical. The newer the provider and shorter the length of training, the more likely it is that the education focuses on classic presentations. In the case of an introductory wilderness first-aid course for lay providers, the curriculum may focus solely on common wilderness medicine problems, leaving it to the caregiver to intuitively recognize when someone is seriously hurt or ill and requires additional care. The educator's job is to help students learn introductory concepts and assist them in recognizing patterns. As they gain additional education and experience, their ability to understand more complex concepts will evolve. If students are initially overwhelmed with too much detail, they will struggle to develop the framework on which to attach their future learning.

Simulations, scenarios, and case studies are useful tools to reinforce and apply learning. One of the helpful constructs of this type of experience is that the patient demonstrates a response to the provided treatment. As discussed above, scenarios have a time limit dictated by the structure and logistics of the setting. As a result, in order to illustrate a specific learning point, scenarios are often crafted with artificially accelerated patient responses or changes. For instance, in an effort to guide the caregivers toward a particular decision, the facilitator may instruct the patient to change his or her vital signs to indicate improvement or deterioration over the course of 10 minutes, whereas this change might more realistically occur over a longer time span. Students, especially those without extensive medical experience, may perceive that rapid change is typical and become confused when they do not see the same pattern in a real patient. It is also presumed that any given learner intervention will produce a notable outcome, either favorable or unfavorable, in the patient presentation. The educational risk is that the student may leave a class believing that the artificial construct of a scenario represents reality. A typical example is the notion that applying glucose paste to the gums of an unconscious patient

TABLE 113-3 Feedback Tool B

Expert	Competent	Novice	Beginner
Consistently identifies and can discuss the advantages and disadvantages of the decision-making tool used	Consistently identifies which decision-making tool is used	With coaching can identify which decision-making tool is used	Unaware or unable to identify which decision-making tool is used

for a few minutes (in a simulation) will return the patient to consciousness. Nevertheless, the positive reward of effective therapy likely remains the best teaching strategy. Consideration may also be given to including scenarios during which the patient does not improve or survive.

Some courses are specifically designed to teach rescue and evacuation skills, but most are concerned with managing the immediate needs of a patient. In the parlance of wilderness medicine, this is stated as "Assess and treat the patient, and then make an evacuation decision." The instructor will typically end a scenario at this point. In a true wilderness emergency, however, much of the hard work begins when the decision is made to evacuate the patient. Evacuation is often difficult, lengthy, and stressful for both the patient and rescuers. It is a challenge to prepare students of wilderness medicine to anticipate this hardship. They may be poorly equipped to handle the physical demands of the process, not familiar with providing long-term patient care, and not sufficiently resilient to endure the emotional challenges of a real evacuation. Without a frame of reference for remote places, students may harbor the conscious or subconscious illusion that evacuation is expedient and readily available by an external resource. To avoid this presumption, instructors should discuss methods of evacuation and emphasize that each choice must be tempered by an evaluation of the risks and benefits for the patient and the group. Scenarios may be crafted to reinforce the notion that self-evacuation by an injured individual may be the most reasonable choice. The faculty may design a scenario in which the group facilitates its own supported evacuation as a part of the exercise, so that the experience takes several hours or a day and requires that the group contend with the realities of long-term care for a patient (Figure 113-11).

Yet another limitation of training is artificial group cohesiveness. In general, participants in wilderness medicine education programs are eager to learn and value the experience of a conflict-free environment. Therefore, there is a general commitment to working together. Good educators create a structure that allows students to fill defined roles. In a real-world application, issues with leadership, teamwork, and communication may be far more challenging than the medical issues. Consideration should be given to including curriculum items that train wilderness medicine practitioners to fill leadership roles and to guide teams. Students should be expected to reflect on their experiences with group activities to better understand models and strategies of high-functioning teams.

FIGURE 113-11 Extended scenarios help students experience the challenges of providing long-term care in a wilderness environment, including fatigue, hunger, stress, extremes of temperature, group conflict, and boredom. *(Courtesy Justin Alexandre.)*

FIGURE 113-12 Wilderness medicine providers must learn to work independently and without the support of a larger team. *(Courtesy Shana Tarter.)*

Finally, although a wilderness medicine education program may create the opportunity to make hypothetical decisions, there is no aftermath. Real-world decisions have real consequences. Students of wilderness medicine must embrace the potential need to make autonomous decisions. In the clinical world, health care providers are accustomed to consulting with others with greater experience or expertise. In the remote setting, practitioners must be prepared for a lack of external communication and be ready to make decisions autonomously. Wilderness medicine courses can help prepare students for this eventuality by teaching and assessing decision-making skills. An experienced wilderness medicine faculty can guide students through a process of making difficult decisions and appropriately dealing with their uncertainty. There may be times when the influence of weather, terrain, darkness, and group dynamics alter the preferred medical decision. By providing opportunities for students to consider a multitude of factors in a given situation, the instructor creates the foundation that students will need to function in the demands of a remote environment (Figure 113-12).

TEACHING IN WILDERNESS MEDICINE

GOOD TEACHERS

What of the act of teaching in wilderness medicine? What is unique about the discipline compared with other areas of health care education that calls for wilderness medicine teachers to pay special attention to their delivery? As mentioned before, wilderness medicine instruction is often and understandably disconnected from the environment about which it informs. Teaching the fundamentals of altitude, depth, cold, or heat and their impact on the human condition requires that the initial knowledge base be largely acquired in a "safe" environment. The experiential phase that we presume solidifies learning for wilderness medicine practitioners often occurs in another setting at a different time, if it occurs at all. Therefore, to be effective, the material must be presented by faculty members that possess the ability to captivate and motivate learners. Paul Auerbach proclaimed, "The enthusiasm of the instructor is plainly apparent and can carry or lose the day. Regardless of the educational technique chosen, one must be 'into it' or the students will be soon flocking out of it."[4]

Just as wilderness medicine practitioners must draw from a solid base of knowledge to be creative when providing care in austere surroundings, wilderness medicine faculty must be familiar with and use all of the theory-based tools available to them to be successful, even in less-than-optimal teaching settings. Steve Donelan highlighted the issue by noting, "Instructors tend to assume that if students stay awake and interested, pass the tests, and write nice comments on the evaluation forms, then the course is successful."[20] Good teaching does not just happen. Highly effective wilderness medicine teachers are as proficient with the teaching skill set as they are with the clinical "tools of the trade" in their unique area of expertise.

The credibility of wilderness medicine faculty is paramount. Beyond the obvious reasons for needing credibility as a teacher, most wilderness medicine learners are already well placed in their respective fields with years of educational experience. Moreover, it is not uncommon for wilderness medicine faculty to be addressing participants that are not only proficient at the topic in question but may be leading experts or researchers in that area. According to Auerbach, "If a teacher wishes to do more than read from a script, he or she must have some first-hand experience in the environment. Students are better than we imagine at rating our technical skills."[4]

For years, medical educators have studied the notion that the best clinical teachers all display a common set of characteristics. Numerous authors list qualities of good teachers based on learner surveys and outcomes assessments.[46,47,119] Some of these have special applicability to wilderness medicine education:

- Possess an excellent depth and breadth of knowledge about the topic(s)
- Are highly competent at the skill(s) being taught
- Are highly skilled at interpersonal interactions with learners
- Are enthusiastic about the role of teacher
- Possess good supervisory skills by providing appropriate feedback, timely and clear direction, and easy access to students for questions and guidance

THE EDUCATIONAL ENVIRONMENT

Hutchinson pointed out that "in adult learning theories, teaching is as much about setting the context and climate for learning as it is about imparting knowledge or sharing expertise."[45] Nearly everything that the teacher does influences a student's ability or willingness to learn. Wilderness medicine course planners that account for these factors enjoy a much higher likelihood of success than do those who simply present material with little accounting for process and environment. Two factors that can be influenced by providing the right environment are the motivation of learners and their perceptions of how relevant the material is to their lives. They derive their energy directly from the faculty and will respond in kind to the amount of effort that has gone into providing for the proper learning environment. They are quick to identify a poorly prepared program.

Motivating factors to consider when planning an educational experience include physical needs and comfort issues that may hinder learning, safety and security, group inclusion and identification, self-esteem (making learners feel important and relevant), and self-actualization through self-directed learning. This all leads to academic fulfillment resulting in a deeply ingrained understanding of the material. These mirror Maslow's well-known model for hierarchic needs satisfaction.

Tangible characteristics of the environment that affect learning seem insignificant to the overall goals of the course and are easily overlooked. If they are not properly accounted for in the course plan, learners may sense a lack of respect. The best-presented material by the most captivating, world-renowned teacher will not hold students' attention if students' primary motivational needs are not addressed. These include factors such as food and beverage availability; frequency of rest breaks; ambient lighting, noise, and temperature of the setting; lodging accommodations; access to telephone and Internet connections; access to public transportation and airports; and the availability of recreation during hours when training is not taking place.

Although it is impossible to solve every problem in any setting that is remote or exciting enough to host a wilderness medicine educational experience, problems should be addressed to the extent possible. Decisions should be made early about adequacy of the setting balanced against the need to conduct realistic training in or near the wilderness environment. Compromises may be made that trade some degree of realism for comfort, and vice-versa. Potential problem areas should be made known to participants well in advance so that they may make choices about the importance of these factors and balance them against their own desire to receive the training (Figure 113-13).

FIGURE 113-13 Successful realistic training in wilderness medicine strikes a balance between the competing demands for high-quality training on the one hand and the expense, safety, comfort, and distraction of learners on the other. *(Courtesy Fred Baty.)*

THE CLASSROOM

In any given program, wilderness medicine educators will likely have both indoor and outdoor classroom settings available. Most courses will use both. Although these may seem interchangeable, assessment of their unique physical attributes will allow the educator to properly match the type of material being taught, expectations of learners, and course objectives with the most appropriate location. In either case, it is important to become familiar with the selected locations well in advance and to establish a transition plan that allows learners to smoothly flow from one to the other. Additionally, it is important to properly position amenities, such as restrooms, refreshments, and parking, to be a resource for students.

The Indoor Classroom

Whenever possible the indoor teaching space should be modified to allow for maximal visibility and participation. Furniture may be moved to create a semicircular space the focal point of which is the primary teaching and demonstration location. Arranging the room in a nontraditional fashion begins to engage students early and tends to generate excitement for the upcoming learning experience. When the space does not allow for a semicircular arrangement, an alternate arrangement, such as rows of tables and chairs angled in a chevron pattern, may suffice. This will preserve open floor space at the front of the room for demonstrations. If the number of participants is known, eliminate extra tables and chairs so that students fill all of the seating. This makes the classroom feel full and minimizes the effect of people sitting in the back row to avoid engagement. Because some practical sessions may occur in the indoor classroom, consideration should be given to preserving open floor space for this element of the class. Sometimes this can be accomplished without repeatedly moving the furniture. In small rooms, there may be the need to deconstruct and reconstruct seating arrangements regularly. It can be helpful to store equipment routinely used for outside scenarios near the classroom exit.

The Outdoor Classroom

The outdoor classroom can be an exciting and refreshing setting that adds a dimension to the experience not possible in a building. The location may be as simple as a small grassy area located between buildings, or a local park or wooded area. It could be as elaborate as a permanently constructed amphitheater-style teaching spot found commonly at summer camps. The instructor needs to assess the hazards associated with the outdoor space and actively manage the risks for and with the students. Is the space used by the local population for rest or recreation? Are there poisonous plants or aggressive insects, such as bees or hornets? Is the location too close to a busy road? A well-crafted scenario may be enough of a distraction that rescuers neglect to look for moving vehicles as they cross the street and approach the scene. Students who are not well prepared for the environment may struggle with rain, wind, cold, or heat in the outdoor classroom. The ambient noise may be such that effectively debriefing a practical experience outside may be frustrating. Finally, it is important to establish specific boundaries for the outdoor classroom that allow the instructor to monitor all students visually and to quickly intervene if necessary. This is especially critical for larger rescues or night rescues where patients may be widely dispersed. Consider bringing to the site a portable writing surface such as a dry-erase board or a butcher-block paper pad on a stand. This can be particularly helpful when debriefing students about a scenario, reinforcing principles, or providing instructions. In all cases, be careful to protect equipment in the outdoor classroom. Light gear blows away easily, notes left exposed can become saturated by rain, and stage makeup used in moulage for scenarios that is left in the sun will melt. Establish expectations for care of equipment with students ahead of time, so time is not spent chasing loose objects (Figures 113-14 and 113-15).

TRAINING AIDS

Equipment Considerations

An academic discipline such as wilderness medicine that studies and teaches the practical application of principles in harsh environments must rely heavily on hands-on, experiential learning. As such, educators and program organizers must anticipate the need to provide appropriate and adequate training equipment. It is reasonable to require students to bring appropriate personal equipment for self-care in the outdoors. However, it is not practical or efficient to require them to provide the equipment needed to learn a variety of new skills. With a large group, this means the program will need to provide a substantial amount of training gear. Planners will need to consider how many of each item will be required to ensure that the entire group of learners can practice a skill either simultaneously or in small groups of two to three persons. Examples of equipment include insulating pads, sleeping bags and tarps, bandaging and splinting material, athletic tape, extrication devices, old clothes, demonstration props such as EpiPen trainers, advanced airway trainers, suture kits, and gloves. If only a single example of a particular piece of equipment, such as a litter or portable ultrasound, is available, then the activity must be structured to allow for adequate hands-on time by all students. Finally, planners must establish well-defined and programmed processes for care, maintenance, transport, and storage of equipment.

FIGURE 113-14 Wilderness medicine educators must be comfortable working in both indoor and outdoor classrooms. *(Courtesy Shana Tarter.)*

FIGURE 113-15 Challenging environmental conditions enhance the learning in wilderness medicine training and prepare students to function in a wide variety of situations. *(Courtesy Marcio Paes Barreto.)*

Audio and Visual Aids

Audio and visual aids may take many forms, limited only by creativity of the teacher. The most basic may be a sand-covered stone upon which simple diagrams are drawn that communicate simple ideas and relationships. The most complex may be a multimedia presentation that incorporates diagrams, video, audio, and a computer or web-based interactive application to enhance learning by appealing to multiple senses. Despite the obvious advantages afforded by technology in preparing appealing and effective learning activities, pitfalls exist, largely related to the confusing or technically complex nature of the chosen technology.

The basic roles of visual aids are to illustrate the organization of a topic as it develops, to reinforce or highlight key material, and to provide an organizational "anchor" for the group that allows members to take notes, think, pose questions, and keep pace with the session.[23]

Examples of simple "low-tech" aids include terrain models, sand tables, dry-erase boards, paper charts, maps, and butcher-block flip charts. These offer significant advantages to wilderness medicine teachers because they are inexpensive and retain their usefulness in austere settings. The disadvantages of these dependable visual aids include the time required to prepare them, the fact that many are good for only a single use or topic, and their limited flexibility if changes occur in teaching objectives.

Technical audio and visual aids include overhead projectors, video machines, and computer or web-based software-driven and projected presentations. It is common for the modern lecturer to use a computer-based presentation program (e.g., PowerPoint, Keynote, Prezi). These tools make presentation and updating of visual images easy, help organize information, and facilitate presentations in large rooms and to large audiences. These all have the advantages of flexibility and appeal to multiple senses. If used properly and in the right setting, they enhance learning and provide a professional look to a degree that is unattainable with simple devices. However, they can seduce the educator to present entertainment instead of substance. They favor the use of bullet points instead of complete sentences. They can lead the educator into the trap of showing a visual representation of something that, if demonstrated, would more effectively enhance learning. The tendency to darken a room for projection tends to dampen energy in the classroom. The inexperienced instructor may use the prefabricated visual resource as a crutch and default to reading the projected material. Class and conference participants are often oversaturated with computer-based presentations and appreciate the simple diagrams and personal engagement that comes when the educator uses a dry-erase board.

A mistake when preparing computer-based presentations is the tendency to want to use all of the "bells and whistles." There is a wide selection of graphics, animations, and interactive tools available to the educator who has even the most basic familiarity with standard software. The trick to preparing good presentations is to resist the temptation to use them. Anything that distracts learners from the main message of the graphic should be avoided. This includes sound effects, animated characters, moving text, and "wild and crazy" fonts. The best advice is to keep the presentations simple and personally test any presentation in the place where it will be used.

The obvious disadvantages of the high-tech methods to the wilderness medicine educator include expense and reliance upon additional technology, such as electricity, light bulbs, software, power cords, connectors, remote controls, computers, and, of course, Internet access. Not only must each teacher be comfortable with his or her subject, the teacher must know how to use computers and software packages and navigate the world-wide web. Many "high-powered" presentations have been aborted because of lack of a simple piece of equipment, an incompatible software program, Internet access difficulties, or a speaker who is not prepared to work with technologic devices.

Textbooks

Like any tool, textbooks are designed for specific purposes. It is important to address this issue before selecting a book to support an educational activity. The most important factor when selecting a textbook is to choose the right tool for the job. Some are intended to be encyclopedic and used mostly for reference. These tend to be larger and cover topics from a theoretical and evidence-based perspective. Although they act as good references and study resources, they may be unwieldy for use in wilderness medicine courses that focus on skills or are conducted in remote locations. They generally have greater application in the areas of wilderness medicine that cover theoretical and highly technical topics.

Some smaller textbooks are intended for use as summaries of larger works. These can even be condensed into quick-reference pocket versions. The disadvantage of these is the amount of information and important detail that is lost with each "condensation." They are seldom used as primary textbooks for courses; rather, they are adjuncts for rapid access to information already available elsewhere.

A third type of textbook is designed for use as a practical study guide. This type comes in various forms, but all appeal to the more practical areas of wilderness medicine that focus on prehospital care and acquisition of hands-on skills. Course planners may organize an entire curriculum around these highly flexible textbooks, or they may use certain sections to support an existing program of instruction.

Formats for modern textbooks include hard copy, electronic (CD-ROM) formats, and fully Internet-based formats. Publishers commonly integrate hard-copy textbooks with web-based tools that offer advanced features, such as updates, searches, and downloading of graphics and additional information.

Syllabus Material and Handouts

Students typically expect some form of syllabus to complement the learning experience. The main purpose of providing handouts is to supplement material provided in textbooks or presented in class. They are often used when faculty want to either summarize or reorganize information into a format that more closely matches the course's learning objectives. Handouts may be used to provide background information when more superficial treatments of material are offered in textbooks designed for skills-based or case-based learning. Other roles for handouts may be to provide a resource for conducting projects or self-examination and for updating information (e.g., clinical guidelines and procedural protocols) presented in published textbooks. Printed materials have the disadvantage of being less environmentally friendly and are likely to suffer the ill effects of harsh learning environments and daily wear and tear. However, they are portable, making them useful in programs with multiple training sites, practice sessions, and scenarios. Printed materials also tend to create less of a barrier between student and instructor than do digital computer-based materials (Figure 113-16).

FIGURE 113-16 Wilderness medicine classes benefit from portable study materials that can be used by students, both in the classroom and during outside practice and scenarios. *(Courtesy Melissa Gray.)*

Handouts that are meant for preclass preparation should be provided before the session. Those meant to recap or summarize may be best provided after the session to avoid distraction.[23] Some syllabus materials are meant to save students time in note taking by providing key points with spaces provided to fill in additional information. This serves the dual purpose of keeping students engaged and making them think about the information before summarizing it in their own words. This technique carries a risk that important information may be misquoted or missed entirely.

Handouts are sometimes intended for use as comprehensive study and preparation resources, much like a textbook. Settings where this may be most beneficial are resource-constricted courses held in remote locations that are not able to provide standard textbooks for all students to use.

A modern approach to the use of handouts is that of providing course materials in digital format, on a CD-ROM or thumb drive or in a web-based, downloadable version. Course planners must consider whether this serves the needs of the class. An instructor facing a room full of laptops cannot know whether students are focused on the material at hand or are distracted by activities unrelated to the class. This presents challenges to the wilderness medicine educator in that many activities are conducted at locations where the Internet is inaccessible and students may not want to bring computers. Some blend of digital and printed materials generally works well.

Whatever approach is used, a poorly prepared syllabus and support material detracts from learning as much as does a badly conducted session or inadequate teacher. No matter how well prepared and presented the learning activity, students will feel frustrated if they must navigate a disorganized, error-ridden syllabus.

Simulations

A thorough treatment of the history and perspectives of the use of simulation in medical education is offered by Gardner and

Raemer, whose description of the use of this educational tool in obstetrics and gynecology training remains relevant. They point out that among all the techniques available for transfer of medical skills and knowledge, "simulation is a practical and safe approach to the acquisition and maintenance of task-oriented and behavioral skills across the spectrum of medical specialties. It is a means to augment didactic instruction, providing an out-of-the-chair and hands-on experience in a safe environment without harming real patients."[37] The notion that nonhuman objects could be used to train medical practitioners is not new and is being used across many disciplines.[8,90,108,116]

Incorporation of computer- and Internet-based simulation technology across the spectrum of industries has been thoroughly adapted to health care education. Most medical schools and graduate medical education programs incorporate some form of simulation in their curricula.[9,37] Computer-based simulation technology has evolved to the point of offering virtual-world, individual- and team-based scenarios using preprogrammed patients to expand the breadth and depth of options available for medical education.[15,92,102] The potential for increased resources required to conduct this training and the associated expense are offset by expectations for increased quality of medical training and the improved outcomes that result (Figure 113-17).

Simulation technology is being used increasingly in medical training settings to enhance team training. As with any team-based vocation, medical teams that frequently practice their interactions are more effective and efficient. Teams that use simulation tools along with scenario-based role-play benefit greatly. This is particularly useful in first-responder and many other types of hands-on wilderness medicine training courses. Learning and reinforcement of basic teamwork principles are greatly facilitated by using scenario- and simulation-based training. These include leadership, followership, situational awareness, closed-loop communication, critical language, standardized responses, assertive communication, adaptive behaviors, workload management, and debriefing[44,87] (Figure 113-18).

Using simulation with computer-based mannequins and live patient role-play adds a dimension to skills-based training in wilderness medicine not available with traditional teaching methods. Although this tool limits the quantity of information that can be covered and is resource intensive, it is a highly effective means of solidifying learning and conducting reliable and valid assessments of hands-on skills. Except for the important teaching paradigms of austerity, limited treatment resources, and improvisation, its use in wilderness medicine is fundamentally no different than how it is employed in other areas of health care education.

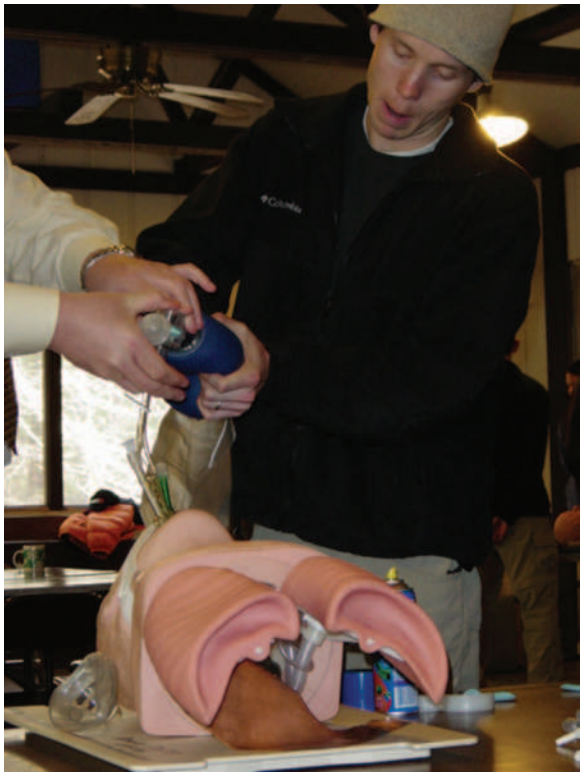

FIGURE 113-17 The use of simulation technology in wilderness medicine education often involves simple, low-technology models to enhance learning. *(Courtesy Fred Baty.)*

FIGURE 113-18 Medical simulation with scenario-based role-play training has become a vital tool in medical education to enhance team-based learning. *(Courtesy Fred Baty.)*

Important factors to consider when planning training using patient simulation are the setting, scene, acting, evaluation, and moulage.[73] The setting can be either indoors or outdoors so long as the proper clues are available to the learners. Highly realistic indoor settings call for elaborate surroundings and are often unnecessary. The basic function is to allow learners to quickly become familiar with the details of the scenario and make treatment and resource allocation decisions based on that information. Outdoor settings add more realism and use fewer resources but are subject to limitations imposed by weather and terrain. Even though prehospital courses in wilderness medicine orient their curricula toward anticipating, recognizing, and managing clinical syndromes using limited and often improvised equipment, using prefabricated and prepositioned props may make training more efficient and assessments more reliable.

The ability of learners to mentally immerse themselves in experiences using simulations seems to be directly related to the quality of the learning experience.[27] No matter the quality and high degree of fidelity of the simulation device used, the willingness of participants to "act the part" as though the situation were real for the duration of the training event facilitates the quality of their learning (Figure 113-19).

Managing the acting can be challenging. Much of what role-players will be asked to do will seem unnatural. Some persons will not have the personality or behavioral repertoire to make good role-players. This results in either overacting or underacting, both of which hinder learning and assessment. Thorough briefings about training goals and setting ground rules for role-players are crucial. Having role-players who are thoroughly familiar with the script ensures that training objectives are met and skills assessments remain reliable. Students within the group can be used for training and derive additional learning benefit from this experience. Outside role-players should generally be used as patients for skills testing. The variation in quality of role-players can be partly overcome by having experienced and thoroughly briefed faculty and examiners at each station.

When available, makeup devices enhance learning by adding a high degree of realism. Makeup may consist of inexpensive improvised items or costly, anatomically correct moulage kits designed specifically for this purpose. The overriding concern when improvising or selecting moulage is whether it enhances or detracts from achieving the learning objectives of the scenario.

FIGURE 113-19 No matter the quality and high degree of realism provided by the equipment, the willingness of participants to "act the part" for the duration of the training event enhances the quality of learning.

If it directly supports the clinical syndrome being portrayed, then it is a good choice. If it does not, then it may confuse learners by causing them to make faulty assumptions. This has the overall effect of incorrect learning of material and leads to unreliable and invalid assessments (Figure 113-20).

Time spent in developing a fair and valid assessment process using patient simulation pays off. As previously mentioned, this is affected by many factors, such as quality and preparation of role-players and faculty, as well as environmental issues that are often beyond the control of the course director.

The notion of computer-simulated training dates back to the 1960s. Modern applications are taking the concept to a new level in the field of health care education. Patient simulation is particularly well suited for skills-oriented basic and advanced life support training in wilderness prehospital courses.[70] This tool

FIGURE 113-20 Simple moulage strategies can be combined with other inexpensive props to add realism to a clinical scenario. *(Courtesy Fred Baty.)*

merges computer technology with fundamental behavior-based adult learning principles to deliver effective teaching. Students are challenged and stimulated to high levels of performance. Information is delivered in a tangible, practical fashion with immediate reinforcement. Learners may repeat scenarios, make on-the-spot corrections of incorrect decisions, and see immediate results. Simulation at this level is more efficient than either problem- or scenario-based teaching, largely due to the high quality of feedback that learners receive when they observe the immediate consequences of their interventions.[70]

Some wilderness medicine training programs may be fortunate enough to have access to life-sized simulation mannequins that run algorithm-based software designed to deliver a response to anything the learner does or does not do. Software can be programmed to demonstrate any number of minor to life-threatening clinical presentations that are interpreted by the student as physiologic changes that would be expected in a real patient with a similar history and status. Interventions such as cardiopulmonary resuscitation, intravenous fluid administration, injectable medications, and endotracheal intubation can be delivered that, if performed properly and in the correct sequence, result in the expected clinical improvement. Information is delivered in a tangible, practical fashion with immediate reinforcement. Learners may repeat scenarios, make on-the-spot corrections of wrong decisions, and see immediate results. Simulation at this level is efficient due to the high quality of feedback that learners receive as they observe the immediate consequences of their interventions.[70] Certain mannequins of this type work well in the controlled indoor training setting with well-trained operators, but are not designed for use in an outdoor training environment.

An additional feature offered by this tool is assessment of learning. In relation to traditional forms of written testing, computer-based patient simulation using scenarios is one of the most effective learning assessment methods. To this already superb tool can be added computer-generated reports and video of the interaction that can be viewed individually or in groups, to reinforce teaching points and make corrections.

EVALUATION OF TEACHING

Assessment of the teaching process is an integral part of completing the education cycle. It is difficult to imagine how any course could flourish without a mechanism to self-evaluate and make periodic adjustments. This is part of what educators are accountable for when promising to deliver a product. Organizations that track, report, and maintain standards for awarding CME and CEU credit require this step to ensure that the quality of health care instruction is maintained at a high level. Evaluation is often viewed negatively by teaching staff. However, if done properly, it can take on a positive quality as a means to provide feedback. All curricula should evolve in ways that are responsive to students' needs. Formal self-evaluation requires a method to organize this process. The main purposes of course evaluation are as follows:[82]

Ensure that teaching is meeting students' needs.
Identify areas where teaching can be improved.
Facilitate allocation of faculty resources.
Provide feedback and encouragement for faculty.
Identify what is valued by educational organizations.
Facilitate curriculum development.

Course directors should look for correlations between results of course evaluations and academic testing. This requires well-constructed evaluation tools. Although a critique of the course should have no impact on whether or not students graduate, it must be treated like any other assessment to yield meaningful results. Several issues must be addressed when designing or selecting an effective evaluation instrument.

Method of Evaluation

There are three basic methods: individual interview, open discussion, and questionnaire and survey. Interview and discussion have limited roles in the overall, long-term process of improvement of most wilderness medicine courses, but have great usefulness in making short-term, on-the-spot adjustments. Questionnaires and surveys have the greatest applicability and will be discussed further.

Fairness and Confidentiality

All participants must be afforded the opportunity to evaluate the educational experience. Although it may not be feasible to make it mandatory, it should be highly encouraged. Questions should be constructed so that they do not unintentionally bias the results according to the responses of one group of learners (e.g., physicians versus EMTs). Most instruments are provided in a confidential fashion, whether or not names are provided on each questionnaire. The issue of anonymity has two schools of thought. One advocates anonymity to reduce the impact of bias and to make sure respondents feel free to offer an honest critique without fear of reprisal. The other requires students to provide their names but takes steps to guard against unintended disclosure and reprisal. This provides for responsible commentary and allows further clarification by individual students if needed. A reasonable compromise is to make it optional to provide names.

Usefulness of the Results

Like any other assessment, the ideal evaluation is reliable, valid, acceptable, and inexpensive.[82] Compromise in any of these areas will decrease usefulness of the instrument. A poorly designed or administered critique wastes valuable resources and time for both respondents and faculty. This lack of respect transforms the process into a meaningless exercise. The most important aspect to ensure that results will be useful is construction of the instrument (see later discussion). Another is to make students feel vested in the course so that thoughtful assessment has a purpose and comes naturally. This must be nurtured in the course design and should have already occurred before critique forms are handed out on the final day. Attend to the principle of proximity. For lengthy courses, ensure that there is time scheduled and reminders given each day to fill out critique forms for each session. A short, overall evaluation of the course can be done at the end. Students may be in a hurry to depart after academic activities are over and therefore rush through, or even omit, the evaluation process. A common technique to ensure that each student completes an evaluation is to require that he or she turns in a form before receiving a graduation or training certificate.

What to Evaluate

Participants may be queried about anything that is relevant to the conduct of the course. However, consideration must be given to the actual usefulness of the information and the time it takes to complete the form. At a minimum, students should be given the opportunity to rate and add additional commentary on the following components[21]:

- Course design
- Textbooks
- Supplemental learning material (e.g., syllabus or handouts)
- Audio and visual aids
- Lecture and discussion sessions
- Skills practice sessions
- Scenarios, simulations, and practice examinations
- Written examinations and quizzes
- Instructors
- The setting (e.g., administration, accommodations, and physical surroundings)

Format of the Evaluation Instrument

Selection of the proper format of the evaluation is critical. An improperly designed instrument with poorly worded questions may lead to meaningless results or faulty assumptions that lead to inappropriate modification of the course design. A valuable instrument is formed with respect for a student's time. Students will not fill it out properly if it is too lengthy or complicated. It should minimize the potential for error and confusion by reducing the amount of work and thought that goes into completing the form. Provide as much unique, identifying, course-related information as possible on the form. The fewer pages the better. One page is best. Instructions must be brief and clear.

A written commentary format gives immediate comprehensible feedback to the faculty that can be either positive or negative. However, it may be superficial and limited in scope. Comments may be difficult to translate into actionable information that leads to course improvements. Evaluations that use this method exclusively have limited reliability and validity.

The multiple-choice format facilitates tabulation and objective comparison. The choice of responses must be broad enough to avoid bias toward either end of the scale. In general, simple good-bad descriptors are less helpful than those that address the function and effectiveness of the item in question. Descriptive adjectives should be selected that match the component being evaluated. For example, adjectives describing helpfulness and effectiveness may be most appropriate when one is asking questions about class materials or procedures. A space for commentary should be provided after each question. Scaled forms on which the student must fill in a circle or cross off a number to rate the specific features of the course take less time to complete and are helpful in managing the results. A quick reminder about the nature of the item being rated may accompany these questions. Likert-type rating scales can be from 1 to 5, or 1 to 7, and may correspond to various forms of descriptors.

No matter what format is chosen, it is a good idea to leave room for several open-ended questions that address the most and least valuable portions of the course, as well as what improvements the respondent recommends. Responses to these tend to be highly contextual based on the background and personality of the student. However, multiple responses from a single class that focus on the same issue or several that are similar across multiple courses may indicate a need for change.

Providing the Results

Course directors should provide tabulated and summarized results of the evaluations to all faculty members. Both group and individual sessions with instructors may be beneficial to discuss the results and select process improvement strategies. Faculty members should see specific comments only about themselves and not those made about other instructors. There should also be some way to inform the students about the results of the evaluations and the resulting actions that were taken.

Evaluation of teaching is a critical component of the overall process of educating adults in any discipline. Learners and teachers at all levels expect this and sometimes look forward to it. With effort in planning and design work, the practice can become a very valuable tool for wilderness medicine educators.

PROGRAM AND CURRICULUM DEVELOPMENT

The notion continues to evolve that teaching in health care should be organized and standardized. How this is best accomplished remains to be determined. The uniqueness of wilderness medicine presents challenges while it affords educators opportunities for innovation in curriculum design. This applies equally to short certification-oriented courses, embedded curricula within longer programs of instruction, and limited CME/CEU programs.

In its most basic form, a curriculum is an expression of community values. To remain viable, it should reflect the current and changing values of the community it serves. Because students will ultimately return to the community to practice, this community of stakeholders should have a say in what they are taught. The educational topics should be directly relevant to their needs. This seems simple, but is an important underlying reason why curriculum design is often controversial in wilderness medicine. Who are the stakeholders? Apart from market dynamics, who gets to decide what should and should not be taught? To what standardizing body do wilderness medicine educators turn for guidance? Where is the evidence upon which to base judgments and decisions?

A growing body of literature seeks to refine what should be included in wilderness medicine education programs. Although there are taxonomies and lists of topics from which to draw, there exists no academic accreditation process or wilderness medicine oversight organization that ensures the relevance of these topics or that they are taught in a high-quality fashion. This allows for great variability in program content and delivery. The National Outdoor Leadership School's (NOLS) Wilderness Medicine Institute uses a triad of attributes: practicality, accuracy, and relevance, to help determine the curriculum content for its programs.

The formalized specialty practice of wilderness medicine is young. It has not yet experienced the scrutiny, peer-review, and standardization of techniques of other medical disciplines. The population of patients from which it can be determined whether a treatment is efficacious is small, which makes it challenging to perform certain types of research. Randomized controlled trials that study laypeople practicing first aid in the wilderness do not exist. NOLS extrapolates techniques from the urban clinical realm and applies them to the wilderness setting.

Absence of evidence-based standards combined with the culture of improvisation may lead the instructor to teach a technique, for example, how to use an improvised traction splint or advanced airway, which works well in the controlled classroom environment but fails in the field. Instructors must ask themselves whether anyone has successfully performed this technique outside the classroom or conference workshop. Often the answer is no, or at best, the sample size is small. In the absence of evidence or personal experience, seeking an anecdotal or a first-person account of the use of a technique helps reassure that what is taught will be effective when employed in the field.

The culture of medical education at the professional level values the accuracy and validity of information. Curriculum content that is evidence based relies upon established practice guidelines and informed expert opinion. By contrast, layperson first-aid training is often provided by well-intentioned but nonprofessional educators or practitioners who may unknowingly provide impractical practice advice and information that is poorly supported by the evidence.

RETENTION OF LEARNING

Despite increased availability of wilderness medicine education programs and establishment of wilderness medicine certification as the de facto standard for leading trips in the outdoors, there is a paucity of research related to wilderness medicine skills retention. There is a body of research in first-aid and basic life support education that documents rapid degradation of skills and knowledge.[2,6,48,63] In 2012, a targeted research study focused on graduates with no prior medical training or experience of a standardized 16-hour introductory wilderness first-aid course to evaluate knowledge and skills retention, as well as the students' perception of self-efficacy.[100]

The study evaluated knowledge retention, skills retention, and self-efficacy at 4, 8, and 12 months following training. The results demonstrated a few key findings that can help improve the design of wilderness medicine education programs. First and unsurprisingly, participants' skills deteriorated in as few as 4 months after their training experience and continued to deteriorate through the 12 months of the study. Most of the participants had no cause to practice their skills in any meaningful way after their course. Second, performance on a standardized, written knowledge assessment had little correlation to the quality of an individual's skill performance. This reinforces the need to dedicate ample time during wilderness medicine training to hands-on skills and application of knowledge through use of scenarios. First aid is largely a practical skill. Interestingly, an individual's confidence in the ability to perform as measured through the self-efficacy tool also lacked correlation with the ability to treat a simulated patient.

Wilderness medicine educators need to be aware of the limits of retention and design their curricula accordingly. Especially in layperson education, complex explanations and unnecessary detail will be forgotten, and even practiced skills will be quickly lost. A focus on simple, relevant, and practical skills, well-designed and well-coached practice, repetition of practice over time, and use of memory aids may be necessary to ensure competent performance in the field.

WILDERNESS MEDICINE INJURY AND ILLNESS DATA

Of everything that could be taught in a wilderness medicine course, how does the educator choose what is relevant to the audience? A good place to begin is to build an understanding of injury and illness patterns in the wilderness. Although wilderness medicine may be practiced in a variety of settings ranging from recreational camps to expeditions to disasters to remote medical clinics, incident data are relatively consistent. By using these data as the foundation for curriculum content, the educator will avoid developing material that may be overly influenced by anecdote or isolated experiences. Existing data can be roughly divided into data from outdoor adventure programs, remote clinical experiences, and wilderness EMS.

The NOLS Field Incident Database is the largest set of injury and illness reports from educational wilderness expeditions. It is currently in its 30th year, with more than 4 million person-days of experience and 14,000 incidents.[39,66,76] Over the last decade, the pace of research has increased, so there is a more substantial body of work that can inform practice and help focus training and decision-making tools. One can study incident data collected by youth groups, outdoor programs, park visitors, search and rescue teams, climbing programs, trekking organizations, and boating groups.[10,18,32,38,65,84,93,109,112,117] However, there remains a lack of credible incidence data from large segments of the outdoor recreation community, including college-based programs, scouting organizations, and many camps.

It is clear from examination of existing data that small wounds, sprains and strains, diarrhea, and flu-like illnesses make up most of the ailments faced by the outdoor leader, and that serious injury and illness are rare. When its incident database revealed these patterns, NOLS revised its WFR curriculum. Dramatic, unrealistic scenarios were deemphasized, and the focus moved toward developing the patient assessment skills needed to determine the need for and urgency of evacuation, and to address the prevention of wound infections, sprains and strains, diarrhea, and flu-like illnesses (Figure 113-21).

A glimpse of trends in wilderness EMS comes from looking at data from search and rescue teams, the National Park Service, and other state land management agencies. These data include both backcountry and frontcountry wilderness medicine, and reveal a set of serious injuries not seen in the outdoor education data. The data from search and rescue teams are weighted toward injury rather than illness, and, in addition to the expected orthopedic problems, there are deaths due to drowning. When one considers illness, there is a greater tendency for underlying medical issues to play a part in these data, especially at the

FIGURE 113-21 Basic skills, such as ankle taping, are important to include in wilderness medicine training. *(Courtesy Shana Tarter.)*

urban-wilderness interface. Cardiac emergencies are prominent; lung disease, diabetes, and the host of other illnesses in the general population also appear.[31,33,40,42,53,78,80,85,105]

Fortunately, the most common problems encountered in the field are not life threatening and can be identified as musculoskeletal, hygiene-related, and environmentally induced. Unfortunately, when a serious event occurs, field treatment is often limited by resources and evacuation is arduous or complicated.

From a course planning standpoint, one takes away important lessons from the growing knowledge of wilderness epidemiology. The first is the value of including prevention. The limits of practice in a wilderness context argue for a theme of prevention. Another lesson is that the strong presence of hygiene-related and communicable illnesses suggests the need for more attention to best practices in simple activities such as hand washing, cooking, and cleaning.[13,77]

The context of practice influences the content of the training program. Persons leading outdoor groups need to be prepared to manage overuse musculoskeletal injury and care for minor wounds with the goal of preventing infection. They need to know how to manage flu-like and gastrointestinal illnesses and how to recognize when a patient can stay in the field and when the patient needs to be assessed by a provider at a higher level of care. In addition, they need to be prepared to care for traumatic injury, including managing potential spine injuries (Figure 113-22).

The wilderness search and rescue provider is more likely to respond to serious injury or illness and needs to be able to adapt urban skills to the wilderness context; most importantly, the provider needs to have the judgment to know when an advanced skill is appropriate in the austere context, and the consequences of initiating an intervention that might need to be maintained for extended periods in austere conditions.

Persons evaluating and treating patients in a remote clinic setting need to be prepared for a broad scope of practice, especially what is common in the local environment. They need to understand what tools will be available and what will need to be improvised, the available inventory of medications and other therapies and how these might be resupplied, what to expect for evacuation and further care, and how to manage the long-term needs of their patients. The breadth of these learning needs challenges the educator to be thoughtful about including in their curriculum what will be practical and relevant for the student.

FIGURE 113-22 Management of spinal injuries in remote settings is a core topic in most wilderness medicine training events. *(Courtesy Shana Tarter.)*

CONCEPTS AND MODELS

Prideaux described a curriculum as "existing at three basic levels: what is planned for the students, what is delivered to the students, and what the students experience." In practical application, a curriculum should be easily communicated to learners and educators, should be open to critique and modification, and should be easily implemented. More specifically, it should contain four elements: content, teaching and learning strategies, assessment processes, and teaching evaluation methods. The process of curriculum design attempts to form these elements into a tangible, usable device.[97]

Several models of health care curriculum design have been proposed. These evolved indirectly based on changing needs, values, and expectations of society. One that has emerged as being effective with great applicability to wilderness medicine is based on identifying, addressing, and assessing desired outcomes. This is appropriately referred to as "outcomes-based education." Although usually discussed in the context of clinical teaching settings, such as medical schools and residencies, the focus on outcomes is germane to wilderness medicine education. No matter how the details of a curriculum unfold in practice, keeping the focus on outcomes places the wilderness medicine learner at the center of the education cycle. The basic concept of this model requires that educators first decide what the students should know (outcomes), design a program of learning to allow them to achieve it, and then assess whether or not they achieved the desired results. The details of how educators make these determinations describe an elaborate and interesting process.

Numerous versions of curriculum design are used throughout the United States and Europe. Many have been reported in the wilderness medicine literature.[16,70,94-96,120] Steve Donelan has written extensively on the subject and offers detailed guidance.[21,25-29] Nearly all courses use a combination of techniques to deliver material to learners. A focus on outcomes is a common theme.

STEPS IN DESIGNING A CURRICULUM

The success or failure of any educational experience goes far beyond a title. Simply using a wilderness medicine label may initially attract enthusiasts. However, failing to deliver a rewarding learning experience that is rooted in fundamental educational concepts, that leverages the most modern technology when applicable and practicable, and that is clinically and practically useful in the field will send would-be attendees looking elsewhere for ways to spend their valuable time and money. The design of the curriculum lies at the heart of this issue. McGraw and Gluckman reported on the results of their efforts to bring wilderness medicine to undergraduate medical education at the University of Pennsylvania School of Medicine. A survey following the course indicated that a large number (40%) of respondents found the course to be the best experience they had undergone in medical school.[75] As Steve Donelan indicated in his commentary on their report, medical schools may have much to learn from these nontraditional courses, given the strength of their curricula and overall course design, quality of teaching, and relevance of the clinical information contained therein.[29a]

All aspects of curriculum design should be well thought out before resources are allocated. The general sequence starts with identification of the desired outcomes, or what the students should be able to do (including a learning needs assessment), addresses specific content (topics to be taught), selects teaching methods, develops learning assessment instruments, and, finally, constructs tools to evaluate the process.

Desired Outcomes

Outcomes are addressed on two levels: the overall course goals or objectives, and specific learning objectives for each session or activity. As discussed above, course goals describe the overall purpose for students attending the course. This may include a job- or skill-related certification or simply advancement of their general fund of knowledge. It addresses what they should be able to do or know after completing the entire program. All activities related to the formal curriculum should contribute in some way to these goals. This is similar to a large corporation that does institution-level analysis of its mission, vision, goals, and objectives. Any action resulting from this strategic planning that does not contribute in some way to the mission of the organization is at best distracting and possibly a hindrance. Individual learning objectives can be viewed in this context. Accomplishment of the course goals depends on them.

Two sources, or stakeholders, should be queried to determine outcomes at both levels. Potential learners may be asked using various methods (polling, focus groups, and questionnaires) what they think is important and what they would most like to learn. Organizations that hire or interface with potential graduates of the course may be asked for their input on what skills, knowledge, and qualities the graduates should possess. The goals and objectives should be formalized, written, and distributed to anyone involved with curriculum design. They serve as a compass to guide all planning and design efforts.

Determine the Content

After the course objectives are established, they are used as a basis to begin selecting major content divisions or sections. There is no "best" method of dividing the information, but it is generally agreed that sections should be easy to support with effective teaching and assessment methods based on sound learning theory (e.g., problem-based versus lecture-based courses, small-group discussion versus hands-on practical exercise). The organization of the original WMS WPHEC objectives suggests sections devoted to basic science, clinical science, EMS and evacuation procedures and equipment, field craft, and prevention. The major sections are further broken down into subsections or topics. The basic science section might be divided by topic-specific reviews of anatomic or physiologic systems. The field-craft section might be broken down into land navigation and wilderness survival. Land navigation may be further divided into sessions on map reading, compass use, celestial navigation, and use of global positioning system devices. It is this final level for which specific learning objectives are written. There are no absolutely right or wrong answers in selecting the specific content of a course. As long as the basic steps are followed, a suitable solution will reveal itself.

Select Teaching Methods

Methods for delivering the information should be selected after the course content has been established. Course planners should make use of several techniques and, if possible, vary them daily to maintain student interest. An entire day of hands-on practical exercise in frigid temperatures may detract as much from learning as a 10-hour day of back-to-back lectures. Intermixing the techniques by spending 2 hours outside and 2 hours indoors in small-group work, followed by 2 more hours outside, capped off with an hour or two of lecture at the end of the day, is an example of this type of variation. The only limits are the imagination of the course planners and simple logistics, such as moving or transporting learners and equipment between venues. Planners should make maximum use of the various forms of problem-based instruction and small-group work. Lectures should be limited to introductions and topics that absolutely do not lend themselves to the aforementioned techniques.

Of the steps in curriculum design, selection of teaching methods may be most influenced by the physical setting of the course. This includes the climate, terrain, and accommodations for teaching and lodging, as well as available support and equipment. The setting will sometimes be preestablished, forcing accommodations in curriculum design. At other times, the curriculum may contain flexible elements that will change as the features of the location change and unexpected opportunities arise.

Select Learning Assessment Instruments

Assessment of learning derives directly from the course objectives that are supported by the learning objectives. Written testing allows assessment of both. Some questions may be intended to evaluate knowledge of facts addressed by learning objectives from individual sessions. Others address the synthesis of information drawn from multiple sessions and in different sections. Written tests or quizzes can be used for formative assessment, whereas hands-on skills testing using scenarios and role-players may be used in practice, formative, and summative (end-of-course) roles. For some courses, skills-based assessments may be out of place, forcing planners to be skilled at constructing written examinations. The main concept in constructing assessment tools is to develop them based on well-written session and course objectives.

DEVELOPING THE COURSE EVALUATION

Evaluation of the course is the final step in the education cycle and curriculum design. Reserving this until last does not diminish its importance. Many highly effective examples of evaluation tools exist. Adhering to basic principles discussed earlier will lead to an effective instrument that informs continuous improvement and curriculum modification.

PLANNING FOR CONTINUING MEDICAL EDUCATION

Educational experiences intended to assist practitioners in maintaining currency, refreshing eroded skills and knowledge, or adding new skills and knowledge are vital to safety and viability across the spectrum of health care, including wilderness medicine. Despite the importance and use by all health care disciplines, there is a relatively small body of evidence beyond tradition, anecdote, and expert opinion to support use of any given educational technique or set of techniques over any another in planning and delivering CME.[89] Guidelines produced by some specialty-oriented professional organizations are based on evidence from the existing body of educational research. These attempt not only to elevate the effectiveness of CME but also to standardize training techniques within the discipline and inform the industry that has grown up to produce continuing education.[81] The body of literature on which these guidelines are based is not large and reflects the tremendous difficulty inherent in studying education in a way that is based on outcomes and that allows reliable cause-and-effect conclusions. It seems reasonable, however, to assert that continuing education for health care should adhere to fundamental principles of adult education. For example, augmenting a course based on a traditional lecture format by using multiple approaches for delivering information, such as multimedia presentations or interactive, small-group, case-based discussion, will enhance energy and improve learning. When practical to the setting, hands-on, practical exercises using scenario-based simulation is a preferable method to refresh, maintain, and learn new psychomotor skills.[1,57,89]

Development of programs designed to award credit for CME or CEU follows the same basic steps with respect to curriculum content. There are challenges unique to this type of activity that deserve special mention. The venue (setting) is more likely to affect the program of instruction, whether it is completely lecture based or uses a mix of teaching styles. Learners at CME/CEU events are more apt to form judgments about value based on the perceived quality of what they received balanced against how much they paid. Participants expect adequate physical space, facilities, accommodations, and amenities.

Many participants seek recreational diversion in addition to the learning experience. This must be addressed in the logistics planning and schedule. Holding an event at an attractive location with abundant recreational opportunities, and then cramming 50 hours of wonderful training into 4 days with no time for recreation will frustrate CME/CEU learners.

The selection process for faculty is often limited by the budget and availability of teachers. Although convention holds that only the most highly proficient and credentialed faculty should be selected, reality often forces a different approach. The search should begin early, because good teachers are highly sought after and have busy professional lives. Program chairs should attempt to obtain a commitment as early as possible and make a viable contingency plan for those that have to cancel or simply do not respond. The design of the program of instruction is closely linked to the selection of faculty for CME/CEU events. The notoriety of teachers often drives selection of their area of expertise as a subject in the curriculum. This also makes contingency planning all the more important when high-profile speakers need to cancel. Learners committed to a topic and speaker may feel slighted when the topic is not delivered or a substitute teacher appears.

After a program of instruction (curriculum) is set and faculty members are chosen, course materials are developed. Program chairs have two basic options to get this accomplished. They may establish the curriculum early, including learning objectives, and then ask faculty to develop and submit original material. This requires that faculty be given specific guidelines about how to prepare the materials, including the format and length. Standardization of presentation materials provides a professional appearance to the program that helps achieve buy-in from participants. The expertise, responsiveness, and quality of product vary greatly, so program chairs are wise to begin this process a year in advance. Another method is to provide prepared materials to the speakers in advance. They may or may not be allowed to make modifications depending on the desires of the program chair. This method has the advantage of being centrally controlled, dependable, and flexible when faculty members cancel. However, the workload of the program chair is increased because all materials must be developed, reviewed for accuracy and currency, and printed or otherwise reproduced.

Perhaps the most difficult part of conducting CME/CEU events is managing the administrative, business, and marketing tasks. These include contracting for venues, lodging and accommodations, speakers, printing, automation and training support, and materials. Developing marketing materials, such as flyers, brochures, and websites, requires skill with graphic design and layout and is usually beyond the expertise of most program chairs. A poorly designed brochure can kill an otherwise high-quality event. Arranging for CME/CEU credit, as well as the interface with the awarding organizations, poses a significant workload challenge. Course materials, including certificates, evaluation forms, syllabus, handouts, administrative guides, electronic storage media, and access to contracted wireless and on-line resources, must all be coordinated and produced. It is recommended that professional assistance be sought for these critical tasks at least 1 year in advance.

Using an organized approach to program and curriculum design that directly addresses objectives and follows the basic conventions discussed here will lead to successful outcomes, no matter the level of learner or type of activity.

PROFESSIONAL ORGANIZATIONS AND TRAINING PROGRAMS IN WILDERNESS MEDICINE

PROFESSIONAL SOCIETIES

Professional societies in the United States and elsewhere have guided establishment of academic standards in wilderness medicine education. These organizations typically sponsor CME events through large, sometimes international, meetings to further education, research, and international cooperation and sharing of knowledge. The WMS and the International Society for Mountain Medicine sponsor educational activities and publish their own peer-reviewed journals *(Wilderness and Environmental Medicine, High Altitude Medicine and Biology)*. The WMS, for example, hosts CME events and offers fellowship recognition to members through its Academy of Wilderness Medicine. Several professional societies, including the American College of Emergency Physicians and the Society for Academic Emergency Medicine, possess wilderness medicine sections or interest groups. Other organizations, such as the Divers Alert Network and National Ski Patrol System, focus on specific content areas (Box 113-8).

BOX 113-8 Professional Societies Related to Wilderness Medicine

United States	
Aerospace Medical Association	http://www.asma.org
American Alpine Club	americanalpineclub.org
American College of Emergency Physicians	acep.org
Appalachian Center for Wilderness Medicine	appwildmed.org
Divers Alert Network	diversalertnetwork.org
Institute for Altitude Medicine	altitudemedicine.org
International Society of Travel Medicine	istm.org
Mountain Rescue Association	mra.org
National Association for Search and Rescue	nasar.org
National Ski Patrol	nsp.org
Society for Academic Emergency Medicine	saem.org
Undersea and Hyperbaric Medical Society	uhms.org
Wilderness Medical Society	wms.org
Europe and Asia	
Austrian Society for Mountain and High Altitude Medicine	alpinmedizin.org
German Society for Mountain and Expedition Medicine	bexmed.de
Himalayan Rescue Association Nepal	himalayanrescue.org
International Climbing and Mountaineering Federation	theuiaa.org
International Commission for Alpine Rescue	ikar-cisa.org
International Society for Mountain Medicine	ismm.org/
Japanese Society of Mountain Medicine	jsmmed.org/
Mountain Medicine Society of Nepal	mmsn.org.np/
Swiss Society for Mountain Medicine	mountainmedicine.ch

CERTIFICATION PROGRAMS FOR OUTDOOR RECREATION AND EDUCATION

Wilderness medicine courses and certification programs exist in first aid, search and rescue, and other advanced topics for laypeople, first responders, physicians, and allied health professionals. In the past 20 years, these programs have proliferated. Growth of wilderness medicine education may be attributed to increasing accessibility of short-duration training for outdoor users, broadening scope of EMS response in nonurban or disaster settings, and the increase in training and certification requirements for outdoor leaders and guides. Although there presently is no consensus for an industry-wide, national standard for outdoor leader wilderness medicine training, the trend, influenced by leading groups in the field (e.g., the Wilderness Risk Managers Conference, accreditation organizations, insurance companies) or by land management permit requirements, is toward some form of certification in wilderness medicine. The Association for Experiential Education has program accreditation standards, which include a policy that wilderness programs enacted at least 4 to 6 hours from definitive care have at least one leader with WFR certification.[72] The American Camp Association requires the presence of persons who have completed, at a minimum, a 16-hour wilderness medicine course when access to EMS is more than 30 minutes.[3] NOLS requires WFR training for its field staff.[88] Outward Bound requires WFR training for the field staff if a program is more than 1 hour from definitive medical care[68] (Box 113-9).

In the 1970s, after decades of small-scale "mountain medicine" educational programs, modern wilderness medicine programs began in earnest. This occurred in tandem with growth of the outdoor education industry in order to meet the needs of trip leaders who needed more than urban-oriented first-aid courses.

In the early years of modern wilderness medicine programs, instructors, who were often outdoor enthusiasts interested in both wilderness and medicine, took what they had learned in urban-oriented, advanced first-aid or EMT courses and adapted the curricula, based on experience and opinion, to fit their needs. Published research was sparse, and courses evolved based on experience, opinion, and available literature. Many of the credible textbooks of the time contained techniques, such as incision and suction for snakebite, that are now considered ineffective. Others included treatment recommendations that were beyond the scope of practice of a lay medical provider. At the time it was the best advice available.[34,67,121] In recent years, a group of providers of wilderness medicine courses have worked to define course content based on evidence and experience, resulting in publication of consensus statements on the Scope of Practice for both Wilderness First Aid (WFA) and WFR certifications.[50,51]

BOX 113-9 Wilderness Medicine Training Providers

Advanced Wilderness Life Support	awls.org
Adventure First Aid	adventurefirstaid.co.uk
Adventure Medic	theadventuremedic.com/courses/
Adventure Medical Consultants	lundycharters.com/maritime-and-wilderness-medicine/wilderness-first-responder
Aerie School of Backcountry Medicine	aeriemedicine.com/
All Aid First Aid	allaid.com.au/
American Red Cross	redcross.org/take-a-class/program-highlights/cpr-first-aid/wilderness-sports-pets #wilderness-remote-first-aid
American Safety and Health Institute	hsi.com/ashi/wildernessfirstaid/
Backcountry Medical Guides	backcountrymedicalguides.org/wilderness-first-responder/
Canadian Wilderness Medical Training	cwmt.ca/
Center for Wilderness Safety	wildsafe.com/
Coconino Community College	coconino.edu/list-of-course-descriptions/327-emergency-medical-services-ems
Desert Mountain Medicine	desertmountainmedicine.com/
Ecomed	ecomed.com.au/
Enviro-Tech International	etisurvival.com/wldmd.htm
Expedition Medicine	expeditionmedicine.co.uk
ExpedMed	expedmed.squarespace.com
First Lead	firstlead.com/
Foster Calm First Aid	fostercalm.com/
Front Range Institute of Safety	frisfirstaid.com
Great Smoky Mountains Institute	gsmit.org/wfr.html
Highlands Wilderness Training Institute	scotthembruff.wix.com/wildernesstraining#!wilderness-first-aid-training-courses/c8jf
International Wilderness Leadership School	iwls.com/courses/activity-2/first-aid-rescue/
Longleaf Wilderness Medicine	longleafmedical.com/
Mountain Education and Development LLC	mountained.com/medical
Muir-Walker Medics Cooperative	uk.coop.muir-walker-medics-co-operative-limited
National Outdoor Leadership School Wilderness Medicine Institute	nols.edu/wmi/
Outdoor Emergency Care	oectraining.com/courses
Pacific Alpine Institute	pacificalpineinstitute.com/coursedescriptions.html
Peak Emergency Response Training	peakemergencytraining.com
Remote 1st Response	remote1stresponse.com/
Remote First Aid Training Academy	remotefirstaid.com/courses
Remote Medical International	remotemedical.com/
Remote Rescue	remoterescuemed.com/
Rescue Dynamics	rescuedynamics.ca/emergency.htm
Rocky Mountain Adventure Medicine	adventuremed.ca
Sierra Rescue	sierrarescue.com/course-info/wilderness-first-aid-courses/
Sirius Wilderness Medicine	siriusmed.com/
Slipstream Wilderness First Aid Training	wildernessfirstaid.ca/
Stonehearth Open Learning Opportunities	soloschools.com/
University of Vermont	uvm.edu/cnhs/rems/
Wilderness Alert	wildernessalert.com/
Wilderness Emergency Care	wildernessemergencycare.com/
Wilderness Emergency Medical Services Institute	wemsi-international.org/
Wilderness First Aid	wfa.net/
Wilderness First Aid Australia	wildernessmedicine.com.au/
Wilderness First Aid Consultants	wfac.com.au/
Wilderness First Aid Course	sites.google.com/a/wildernessfirstaidcourse.org/wilderness-first-aid-course/home
Wilderness Medical Associates	wildmed.com/
Wilderness Medical Consultants	wildernessmedicalconsultants.ca/
Wilderness Medical Training	wildernessmedicaltraining.co.uk/
Wilderness Medicine	wilderness-medicine.com/
Wilderness Medicine Outfitters	wildernessmedicine.com/
Wilderness Medicine Training Center	wildmedcenter.com/
Wilderness Medicine of Utah	wmutah.org/
Wilderness Medicine Outfitters	wildernessmedicine.com/
Wilderness Medicine Training Center	wildmedcenter.com/
Wilderness Safety Consultants	wsc2.com/

TABLE 113-4 A Comparison of Wilderness First-Aid and Wilderness First-Responder Courses

Wilderness First Aid (16 to 24 Hours)	Wilderness First Responder (70 to 80 Hours)
Wilderness first-aid courses are basic layperson first-aid programs. The curriculum focus is on performing a simple physical examination to identify obvious injuries or abnormalities; assessing signs, symptoms, and vital sign patterns; preventing medical problems anticipated by the activity and environment; treatment focused on stabilization of emergencies, initiation of specific and appropriate medical treatments (splints, wound care, spine injury management, managing environmental threats); and conservative decisions on the need for and urgency of evacuation. The wilderness first-aid curriculum neither includes such practices as administering medications other than epinephrine by autoinjector for anaphylaxis, nor does it include selective spine immobilization.	Wilderness first-responder courses are first-aid programs intended for nonmedical professionals who are acting as primary caregivers in a remote setting or as second rescuers for more highly trained persons. The scope of practice for a wilderness first responder is to prevent illnesses and injuries; identify illnesses and injuries; initiate reasonable and prudent field management; and identify red flag signs and symptoms necessitating evacuation for potentially life-threatening problems. The wilderness first responder is taught selective spine immobilization protocols and reduction of a selected set of joint dislocations.

Lay provider certification programs can be broadly divided into WFA (16 to 24 hours), Wilderness Advanced First Aid (32 to 40 hours), WFR (70 to 80 hours), and WEMT (150 to 200 hours). These programs are typically offered in a traditional classroom setting with access to out-of-doors practice space. They mix lectures with skills and scenarios. Successful completion of examinations results in certification lasting 2 to 3 years. Though the breadth and depth of topics covered in these courses vary, the courses share a foundation as defined in the WFA and WFR scope of practice documents (Table 113-4).

More recent developments include semester-long programs blending medicine, clinical experience, and rescue training. These programs average 12 weeks, include multiple certification opportunities, and offer undergraduate college credit. Some include international clinical experience; others focus on extended wilderness travel and technical rescue.

TRAINING FOR HEALTH CARE PROFESSIONALS

A similar series of certification programs exist for professionals. In addition to earning certifications, participants generally receive continuing education credits. These programs presume preexisting medical knowledge and focus on adapting existing understanding and experience to new contexts, as well as improvisation of equipment and materials (Figure 113-23).

Common certification programs include courses that add the wilderness medical skill set to urban EMT certification and advanced life support courses. The specific course and certification vary by provider. These courses typically range from 24 to 48 hours and carry a commensurate number of continuing education hours. Certification lasts 2 to 3 years. The courses are commonly classroom based, but may include outdoor experiences and perhaps an extended rescue experience. They provide a solid foundation for health care professionals looking to expand their sphere of practice, become involved with a local outdoor organization, or join a search and rescue team (Figure 113-24).

FIGURE 113-23 Wilderness medicine caregivers must develop skills to improvise equipment from the resources at hand. *(Courtesy Gates Richards.)*

For individuals seeking deeper learning in wilderness medicine, there are more extended education programs. The WMS offers the Fellowship of the Academy of Wilderness Medicine. Successful completion of the education and experience requirements allows the WMS member to use the designation of FAWM to indicate this accomplishment.[118] The internationally recognized Diploma in Mountain Medicine includes intensive skills training focusing on the care of patients in technical mountain terrain.

MEDICAL SCHOOL, RESIDENCY, AND FELLOWSHIP OFFERINGS

Wilderness medicine training is gaining prominence within traditional medical education venues. Although it is historically closely aligned with emergency medicine, it can also be found as a component of family medicine, military medicine, and

FIGURE 113-24 Specialty training courses help urban prehospital care providers adapt their knowledge to wilderness and austere environments. *(Courtesy Gates Richards.)*

BOX 113-10 Universities and Other Organizations Offering Electives in Wilderness Medicine for Medical Students

Belize Institute for Tropical and Wilderness Medicine	medschool.umaryland.edu/osr/training-belize.asp
Brown University	brown.edu/academics/medical/education/preclinical-electives/biol-6652
Cornell Medical College	cornellwm.org/
George Washington University	gwu.edu
Johns Hopkins University	hopkinsmedicine.org/emergencymedicine/residency/wilderness_medicine.html
Maine Medical Center	wildernessmedicineelective.com/
Marshall University	jcesom.marshall.edu/residents-fellows/programs/family-medicine/wilderness-medicine
NOLS and Harvard Affiliated Emergency Medicine Residency	nols.edu/wmi/courses/medicineinthewild.shtml
Saint Louis University	slu.edu/medicine/surgery/division-of-emergency-medicine/emergency-medicine-student-resources/medical-student-rotations
University of Arizona	medicine.arizona.edu/node/18288/wild-new-wilderness-medicine-program-ua-hones-patient-care-skills-austere-conditions/wild
University of California San Francisco, Fresno	fresno.ucsf.edu/undergrad/wilderness_medicine.html
University of Colorado	coloradowm.org/
University of Iowa	uiowa.edu/
University of Michigan	medicine.umich.edu/dept/emergency-medicine/education/other-programs/austere-environment-medicine
University of Nevada Las Vegas	medicine.nevada.edu/ome/electivesl; lasvegasemr.com/wilderness-medicine.html
University of New Mexico	unmmountainmed.com
University of South Alabama College of Medicine: Longleaf Wilderness Medicine	longleafmedical.com/medical-electives.html
University of South Carolina	emergencyresident.com/info_wilderness_medicine.php
University of Utah	awlsmedstudents.org/studentelective.html
University of Virginia	med.virginia.edu/emergency-medicine/education/medical-student-education/wilderness-medicine
Wilderness Medical Associates, Canada	wildmed.com/wilderness-medical-courses/medical-professionals/wilderness-medical-elective
Wilderness Medical Society	wms.org/conferences/

disaster medicine. Wilderness medicine courses in medical schools and residencies have typically been formed by the efforts of an individual faculty member or students with personal interest in the topic. Until recently, little support existed for content consistency. However, within the past few years, there have been focused efforts to define core and elective topics for both student and resident electives and postresidency fellowships.

In 2014, there were at least 26 wilderness medicine electives for medical students and 12 for residents, more than three times the number in 2005. These electives typically last from 2 to 4 weeks and blend classroom learning with a wilderness experience. The emphasis of a given elective often closely parallels the interests of its medical director. Introduction of a wilderness experience creates an opportunity for instruction in general outdoor skills and preparedness. The results of an effort to achieve a consensus regarding core and elective elements was published in 2014.[61] Although this paper is largely based on expert opinion, it may help standardize the elective content for future programs. The growth of medical school electives in the past decade lends support to the notion that medical students value opportunities for education outside their traditional study topics. Wilderness experiential outings used as socialization events for an introduction to medical school further support the value of wilderness medicine education (Boxes 113-10 and 113-11).

More formalized effort is being put into standardizing content and recruitment and application processes for 1-year wilderness medicine fellowships. There exist at least 14 such fellowships, with more being developed. The American College of Emergency Physicians Wilderness Medicine Section established a task force to develop standardized content and a core curriculum for these fellowships and published the results of their 4-year project in 2014[69] (Box 113-12).

Beyond elective and fellowship opportunities, less formal structures exist for medical students and others to explore their interests. The WMS lists nearly 50 student interest groups on their website.[107] The Medical Wilderness Adventure Race (MedWAR; see Chapter 114) blends wilderness medicine skills with adventure-style racing and hosts events across the United States.[79] In addition, medical students can access the widely available certification training programs mentioned above.

CONTINUING MEDICAL EDUCATION CONFERENCES AND TRAVEL

An Internet search for wilderness medicine continuing medical education (CME) produces hundreds of results. The ability to combine required educational experiences with new and interesting content or possibly adventure travel draws professionals

BOX 113-11 Universities and Other Organizations Offering Electives in Wilderness Medicine for Residents

Belize Institute for Tropical and Wilderness Medicine	medschool.umaryland.edu/osr/training-belize.asp
Central Maine Medical Center	cmmcfmrp.org/wimp-curriculum
Cornell Medical College	cornellwm.org/
George Washington University	gwu.edu
Johns Hopkins University	hopkinsmedicine.org/emergencymedicine/residency/wilderness_medicine.html
University of California San Francisco, Fresno	fresno.ucsf.edu/em/parkmedic/
University of Montana Wilderness Institute and Aerie School of Backcountry Medicine	umt.edu/wi/education
University of South Carolina	emergencyresident.com/info_wilderness_medicine.php

BOX 113-12 Universities and Other Organizations Offering Fellowships in Wilderness Medicine

Baystate Medical Center Wilderness Medicine Fellowship	baystatehealth.org/education-research/education/fellowships/wilderness-medicine
Eastern Virginia Medical School International and Wilderness Medicine Fellowship	evms.edu/education/centers_institutes_departments/emergency_medicine/fellowships/international_wilderness/
George Washington University Fellowship in Extreme Environmental Medicine	smhs.gwu.edu/emed/education-training/fellowships/environmental
Madigan Army Medical Center Austere and Wilderness Medicine Fellowship (Department of Defense only)	mamc.amedd.army.mil/education/graduate-medical-education/fellowships/austere-and-wilderness-medicine.aspx
Massachusetts General Hospital Wilderness Medicine Fellowship	massgeneral.org/education/fellowship.aspx?id=94
Medical College of Georgia at Augusta University Wilderness Medicine Fellowship	augusta.edu/mcg/em/ed/fellowships/wilderness/fellowship
Stanford University Wilderness Medicine Fellowship	emed.stanford.edu/specialized-programs/wilderness-medicine/fellowship/.html
State University of New York Upstate Medical University Wilderness and Expedition Medicine Fellowship	upstate.edu/emergency/education/fellowships/wilderness.php
University of California San Diego Wilderness Medicine Fellowship	healthsciences.ucsd.edu/som/emergency-med/education/fellowships/wilderness-medicine/Pages/default.aspx
University of California San Francisco, Fresno, Wilderness Medicine Fellowship	fresno.ucsf.edu/em/wilderness/
University of Colorado Wilderness Medicine Fellowship	coloradowm.org/
University of New Mexico Wilderness Medicine Fellowship	unmmountainmed.com
University of Utah Wilderness Medicine Fellowship	medicine.utah.edu/surgery/emergency_medicine/fellowships/wilderness_medicine
Yale School of Medicine Wilderness Medicine Fellowship	medicine.yale.edu/emergencymed/fellowships/

from many backgrounds. CME experiences provide an opportunity for individuals with similar interests to meet and engage. These experiences often draw well-known faculty with wilderness medicine research activities. The trend is for delivery of information through lectures or large-conference general sessions. Although this is a reasonable medium for conveying new knowledge and sharing research, it often lacks the opportunity for any form of practical application of the new material. Participants of CME events may still be ill-prepared to manage a situation that has been described to them but to which they have not been exposed in any tangible manner. Conference workshop sessions generally provide more opportunities for skills development, sometimes in a classroom, sometimes in the field. Participants should be encouraged to take advantage of these opportunities to develop confidence in functioning in remote environments.

Some CME programs include a travel component. This allows participants to practice skills in environments other than a classroom. The structure of these programs varies, with some offering day outings and others a more extended expedition experience. In either case, the participant is able to improve his or her wilderness travel knowledge in addition to gaining hands-on wilderness medicine experience.

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Complete references used in this text are available online at expertconsult.inkling.com.

CHAPTER 114

MedWAR: Medical Wilderness Adventure Race

MICHAEL J. CAUDELL, DAVID J. LEDRICK, AND HILLARY R. IRONS

Simulations and scenarios are widely used for teaching in many professions, including wilderness medicine.[9] The last 10 years have seen a significant increase in the use of simulation, which has become an established part of graduate medical education. There is a growing body of literature on how best to use simulation equipment and instructional methods.[18,22,28,31,38] Simulation-based curricula have been developed to teach specific clinical skills, such as performing procedures, using teamwork, and making decisions, at all levels of medical training. Many residency programs have incorporated simulation as a formal part of a curriculum,[1,3,6,7,20,25,34,39] including educational programs for rural and wilderness medicine.[11,13,21,24,30] Both low-cost medical models[13,21,30] and highly realistic simulations[11] have been used for outdoor procedural skills and structured outdoor class settings such as advanced wilderness life support classes[11] and even the challenging and restricted space of an in-flight helicopter.[40]

Adventure racing, or the incorporation of multiple endurance disciplines into a single event, has roots that extend as far back

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FIGURE 114-1 The MedWAR logo. *(Courtesy NAEAR and MedWAR.)*

FIGURE 114-2 MedWAR Utah. *(Courtesy NAEAR and MedWAR.)*

as the Karrimor International Mountain Marathon in 1968. The Raid Gauloises was established in 1989 and is considered one of the first modern adventure races. The 1990s were a time of great expansion for adventure racing; the well-known Eco-challenge, produced in 1995, brought adventure racing to a wider audience and inspired other planners to establish races across the country. Adventure race distances range from shorter 2- to 6-hour events (sprint distance) to longer, 3- to 11-day events (expedition distance).[21] In 1998, the United States Adventure Racing Association (USARA) was founded to support the growing sport. Around this time, a number of faculty members from the Medical College of Georgia emergency medicine residency program took up the sport and provided inspiration for the Medical Wilderness Adventure Race (MedWAR) (Figure 114-1).

MedWAR MISSION STATEMENT

MedWAR combines wilderness medicine with adventure racing to teach and test wilderness medicine and survival skills (Box 114-1). Races are sprint distance events and typically cover 10 to 15 miles by foot, bike, boat, or skis. Teams may have three or four members, depending on the race, and may be composed of any combination of health care professionals, emergency personnel, students, and outdoor enthusiasts (Figure 114-2). There are no minimal knowledge or skill requirements and no divisions based on age, gender, or medical skill level. Teams must be self-sufficient and carry their own food and water throughout the race. They must also carry safety equipment and a medical kit. Part of the MedWAR challenge is deciding what to pack in the team's medical kit, just as would occur for an actual wilderness expedition.

THE HISTORY OF MedWAR

The first MedWAR was conceived in the fall of 2000, a few days after the founders competed in their first sprint distance adventure race. The idea became action when a group of medical students seeking a research project approached the Medical College of Georgia faculty and were offered the opportunity to help organize the inaugural event. In April 2001, 22 teams from eight states, along with teams from Canada and visiting students from Australia, spent the day learning wilderness medicine at Wildwood Park near Augusta, Georgia. The original event included several hours of instruction, beginning in the morning. With no time limit, the last finishing teams struggled in at 2:00 AM the following morning. The event has been held in Georgia every spring since, although it has been relocated to a more rugged environment at Fort Gordon. In October 2002, the first event outside Georgia occurred at the Pinckney Recreation Area outside Ann Arbor, Michigan (Figure 114-3).

MedWAR caught on quickly. Many groups of motivated racers sought to bring the race closer to their homes. The first expansion race beyond the original Southeast Race in Georgia and the Midwest Race in Michigan was MedWAR North in Ontario, Canada, in 2003. MedWAR North was unique because it was the first winter race and included Nordic skiing, snowshoeing, and winter mountain biking. During its first year, the race was piggybacked onto a local adventure race, but soon thereafter MedWAR North broke away and held independent events. The MedWAR North racers take advantage of their winter setting by using scenarios with fallen ice climbers and victims of hypothermia, frostbite, and cold-water drowning. Displaying theatrical blood on snow makes for an impressive scene (Figure 114-4).

MedWAR North was the first race organized without the direct involvement of original Medical College of Georgia faculty members. The student organizers worked with the directors of the previous races, who offered advice on logistics, helped vet the scenarios, and assisted in writing questions. The students staged a successful and well-run event. The process, however, made it evident that a more formal mechanism should exist to assist future event organizers, coordinate race schedules, and advertise to participants.

BOX 114-1 MedWAR Mission Statement

To provide medical students, residents, health care professionals, and wilderness enthusiasts with a practical, interactive, and enjoyable curriculum for learning, applying, and evaluating emergency medical knowledge, skills, and techniques in a wilderness setting.

From MedWAR: medwar.org/mission.htm.

FIGURE 114-3 Midwest MedWAR in Pinkney, Michigan. Teamwork in action. *(Courtesy NAEAR and MedWAR.)*

FIGURE 114-4 MedWAR North: a great moulage example. *(Courtesy NAEAR and MedWAR.)*

The first several MedWAR events were sanctioned by USARA, which helped with publicity and event insurance. It became clear that the educational mission of MedWAR meant it occupied a very small niche within USARA. In response, the organization North American Educational Adventure Racing (NAEAR) was created in 2003 to ensure that an event's educational focus would be upheld, regardless of the event format. In an effort to remain consistent, the published curriculum of potential medical issues for all events is the same, although different venues naturally lend themselves to different components. Through formation of a central organization, NAEAR has prevented competition among races in the same region, acted as a resource in writing and maintaining a question bank, and provided faculty oversight for the medical scenarios. NAEAR also offers advice on race organization and logistics and maintains a website for publicity and communication.

The Mid-Atlantic MedWAR began in spring 2006 in Virginia. The first race was held at Fort A.P. Hill with a course that heavily emphasized orienteering. The race has since been moved to Newport News Park, and the course has been changed to a multiloop one. It is now the third largest race held each year, with 35 to 40 teams.

The Northeast MedWAR was held in upstate New York for several years beginning in 2006; however, the original race organizers moved on, and so the race eventually lost support in the area.

MedWAR Utah came onto the scene in 2009 as the first global positioning system–based race. The race takes advantage of the altitude in Park City to simulate high-altitude illnesses and mountaineering injuries. An avalanche beacon is usually buried somewhere along the course.

In fall 2009, MedWAR Tennessee held its first race; races have opened in Pennsylvania and Southern California. Additional expansion races are in planning stages (Box 114-2).

BOX 114-2 Starting an Expansion Race

The rewards of starting a race are great, but it is not without a substantial amount of effort. New races are usually started by groups of interested medical students, residents, fellows, or attending physicians who have previously participated in an established race. Planning a new race takes approximately a year and requires a dedicated group of three to five core race directors and a pool of potential volunteers and racers. They are typically associated with a medical school or residency program, which brings in new ideas and new volunteers with each new class. If you are interested in starting a MedWAR expansion race, you can contact the sanctioning organization North American Educational Adventure Racing at naear@medwar.org.

THE MedWAR MODEL: HOW IT WORKS

MedWAR is an outdoor wilderness event; everything related to a MedWAR weekend pivots around this idea. MedWAR events are held around North America in all seasons; this means that every venue has a particular focus and feel, from the snowy north to the swamps of the southeast. The Midwest event is timed around the autumn changing of leaves, whereas the Utah event coincides with the Wilderness Medical Society's annual winter conference. The outdoor environment dictates everything from how the race will be planned to how competitors will need to prepare. Built-in safety margins and adaptability are crucial to MedWAR event planning; for example, at one venue, the temperature may be much colder and the water levels lower from year to year, and trails may need to be rerouted.

MedWAR is intended to be a safe event that allows each participant to step outside his or her level of comfort; however, it is not without risk. Line 1 of the liability waiver states "the only way to make this event entirely safe is to cancel it." For many competitors, MedWAR is an introduction to wilderness medicine and very often their first adventure race. Competitors are expected to prepare on their own for both the medical challenges and the time spent in the wilderness setting. The nature of adventure racing requires that teams be self-supported; therefore, they must carry adequate food and water for the duration of the event. Depending on the venue, racers may be out of sight of the competition and race staff for hours at a time, in a setting where it is possible to become lost. Race organizers, therefore, should inform competitors about the venue and how to communicate with the teams. Teams need to carry specific gear that would sustain them in the wilderness environment for a period of 24 hours in the event they were significantly delayed on the course. Mandatory gear for MedWAR typically includes a map and compass, a change of clothing, fire starting material, a space blanket, a light source, a whistle, and a water disinfection method. MedWAR courses must be planned with the novice in mind; directions must be more specific than might be the case in a typical adventure race and the trails and waterways used might need to be better established.

Learners at a MedWAR event receive little direct instruction prior to the race. Aside from course briefings and a basic review of water detoxification methods for safety reasons, participants learn through experience and self-preparation. The curriculum is published online prior to the event, and participants are asked to prepare for any of the challenges listed (Table 114-1). Learners are encouraged to carry and use references during the race. The intent of a MedWAR event is to offer competitors a chance to experiment, improvise, and apply principles that they have already learned.

Throughout the MedWAR event, teams encounter simulated wilderness medical emergencies. A team's response to a medical challenge is assessed through demonstration of specific criteria judged by experts to be "critical" to the management of a problem. The race presents several scenarios commonly seen in wilderness settings, and participants are asked to demonstrate their ability to recognize and manage a problem within a range of acceptable alternatives. Each team is allowed to have a unique solution, so long as it follows appropriate principles. In some cases critical actions must be performed in a specific order to be acceptable, such as ensuring scene safety prior to attempting rescue, or checking the neurovascular status of a limb before and after splinting. Some criteria must be met within a specific time to be considered complete, such as securing an airway within minutes of arrival on scene. Each scenario has its educational objectives built into the critical actions. The challenge of managing an unconscious patient who fell while crossing a stream may require that participants assess a scene for safety, perform an initial assessment, including airway and cervical spine protection, and then get the patient safely out of the water (Figure 114-5). There are multiple ways to accomplish each of these tasks, but the focus is on following management principles and demonstrating results. Task penalties are incurred for each missed critical action, thereby providing immediate educational feedback for

TABLE 114-1 MedWAR Curriculum

Type of Management	Specific Conditions Addressed
Musculoskeletal injury management	Strains and sprains Dislocations Fractures: splinting, traction
Soft tissue wound management	Lacerations Burns Punctures: with and without embedded objects Blisters Infection Frostbite or extremity immersion Animal bites Insect bites and stings Fishhook removal
Exposure injury and condition management	Hypothermia: full-body immersion Hyperthermia and heat stroke Altitude or mountain sickness Dehydration Hazardous materials exposure Poisonings Injections (animals, insects) Ingestions (foods, plants, liquids) Contaminated water or water disinfection Food or electrolyte deprivation Lightning and other weather conditions Drowning and river safety Fire issues: smoke inhalation, fire safety Avalanche safety and burial or rescue Crevasse extrication
Systemic injury and condition management	Shock Respiratory conditions and respiratory arrest (CPR) Cardiovascular conditions and cardiac arrest (CPR) Neurologic injuries and conditions Preexisting medical conditions (e.g., diabetes, sickle cell anemia) Diarrhea and fluid loss
General issues	Basic search and rescue Ethical issues in wilderness medicine Legal issues in wilderness medicine Scene assessment skills: multiple patients (wilderness triage) Patient assessment skills: multiple injuries Pediatric issues in wilderness medicine Orienteering Medical kit planning Expedition gear planning Communication issues Transition-to-hospital issues

From MedWAR: medwar.org/curriculum.htm.

participants' performances, a crucial portion of the education that participants gain during MedWAR. Well-trained volunteers are necessary to proctor multiple teams while maintaining the "race pace" atmosphere. Although the medical scenarios are simulated, it is necessary to create a believable scene that can be easily established and maintained by volunteers. Besides the cost of props, important considerations include the ability to transport equipment to scenario locations, having enough volunteers to staff scenarios, and having "victims" who agree to wear moulage. It is often more efficient and realistic to "injure" a team member than to have a volunteer actor. Most equipment is carried by teams as part of their required gear and medical kits. However, some safety equipment, such as personal flotation devices or climbing harnesses, may be provided by the race organizers. Teams might have to "earn" equipment by performing well in a scenario or providing a correct answer to a medical question. For instance, a syringe of "epinephrine" may be earned early in the race to be used later in an anaphylaxis scenario.

FIGURE 114-5 Southeast MedWAR: managing a cervical spine injury while safely moving a patient. *(Courtesy NAEAR and MedWAR.)*

MedWAR is a competitive event, so the atmosphere at the starting and finishing lines is that of a race. However, its primary purpose, and what sets it apart from other races, is the goal of wilderness medicine education. Knowledge and competence are rewarded over speed. Using specific criteria grading supports an educational focus at each scenario. Failure to meet these criteria typically results in the team immediately performing a penalty on site, which serves the dual purpose of slowing the team down and reviewing the missed management principle. Time lost by performing a penalty is generally enough that a team moving slowly and using reference material will do better than a careless team that does not fully solve the problem. Performance bonuses are more difficult to execute at the practical stations due to difficulties with interrater reliability and the complexity of identifying multiple layers of management, but time bonuses may be earned by answering test questions. Questions worded in a typical board examination style, printed and laminated, are sometimes set on trees or stakes to mark the course, thus keeping competitors moving along the same path (Figure 114-6). In some instances, exhibits are used (Figure 114-7). Questions with passwords are also used as orienteering checkpoints or as optional time bonus points to extend the race for high-performing teams and to add a level of team strategy. At a typical MedWAR event,

FIGURE 114-6 Southeast MedWAR: didactic questions keep racers on course. *(Courtesy NAEAR and MedWAR.)*

FIGURE 114-7 Snake identification at Southeast MedWAR: venomous or nonvenomous? *(Courtesy NAEAR and MedWAR.)*

each team moves along the course alone, usually out of sight of the other teams, with the winner unknown until all teams have finished and all didactic bonuses or penalties been tallied.

MedWAR planners have tried to make each event accessible to anyone willing to make the effort to participate. Anecdotally, MedWAR competitors tend to be medical students or residents with a better-than-average fitness level. Race directors have the challenge of creating an event difficult enough to be physically demanding for top competitors but within reach of novices. The Mid-Atlantic race has used two distinct courses to address this issue. Another difficulty in course design is creating a land navigation course for competitors with a wide range of experience in orienteering. Incorporating ropes or water challenges further tests the abilities of competitors and complicates event planning, but also significantly enriches the experience (Figure 114-8). When challenges requiring special skill, strength, balance, or tolerance of heights are incorporated, it is important that competitors are given an opportunity to complete the task with expert instruction and supervision, or to offer them an alternative challenge. On average, a top team can complete a well-planned course in half the time of a last-place team. A common way to extend the race for more competitive participants is to give them optional sections to complete for time bonuses. This section is usually a difficult orienteering challenge in which the team earns greater rewards according to the number of checkpoints they visit. It is sometimes also necessary to reroute slower teams during the race for safety reasons due to time constraints.

FIGURE 114-8 Southeast MedWAR: incorporating physical challenges enhances the race experience. *(Courtesy NAEAR and MedWAR.)*

The competition of a race environment enhances the educational value of a MedWAR event. This competitive aspect lends a sense of urgency similar to that of the stress of a survival situation with consequences for mistakes that make a difference in race outcome. Missing critical actions during a scenario may cause a significant delay or time penalty, and navigation errors may make the difference between finishing on the podium or in the middle of the pack. The place order of finishing gives competitors some measure of comparison with their peers. It also provides a forum for residents to challenge their attending physicians or wilderness medicine clubs from different schools.

There are many logistics challenges in creating a competitive event that sometimes involves upward of 100 participants. Planning the race begins with scouting the appropriate venue and creating a course that is challenging but also negotiable for most participants. Medical scenarios must be situated in areas accessible to volunteers and allow for transport of props and equipment. Rental of portable toilets and generators is sometimes necessary. Further problems include validating the medical scenarios and questions; obtaining permission to use land; securing race insurance; and having ready maps of the area, race T-shirts, and food for competitors and volunteers. Rental of boats, bikes, or ski equipment must be considered. On race day, competitors must be registered, have gear checked, receive race-specific instructions, be tracked on the course, be ushered through challenges without bottlenecks, be accounted for at the end of the race, and have their results accurately scored. After the race, the area needs to be cleaned, gear returned, results posted, and accounting done. In general, planning and executing a race is a 6- to 12-month process.

MedWAR RESEARCH

Although participating students sometimes view MedWAR as a competitive outdoor event with whimsical scenarios and dubious story lines, there has been an effort to maintain a high level of academic integrity in teaching wilderness medicine principles. There is validated research showing the educational value of simulation education. Several subsequent studies indicate that the scenario-based approach used by MedWAR has become an integral part of standard medical education.[1,3,6,7,20,25,34,39]

Initial publications were concept papers outlining the purpose and practicality of MedWAR.[12,14,17] Within 3 years of the first event, several hundred competitors, primarily medical students and residents from midwestern and southeastern U.S. states, had participated at a number of different venues. Each race maintained rigorous academic standards, realistic scenarios, and grading criteria that rewarded appropriate medical practice over speed. Although the agenda was not mandated, races tried to incorporate consistent lessons: a triage or mass casualty scenario, an airway problem, splinting, patient carry, wound care, and general wilderness survival skills. Didactic material was covered either by a written examination or questions posted throughout the race, allowing competitors to use whatever resources they carried, again rewarding a correct over a fast response (Figure 114-9).

While MedWAR was being refined, there was a push within medical education to emphasize simulation-based teaching as an effective way to educate students and residents. MedWAR is a simulation event that gives practitioners an opportunity to practice wilderness medicine skills in a safe environment. One commonly tested skill is the ability to obtain a surgical airway. A typical scenario requires a team to demonstrate noninvasive techniques first and then have the condition of the airway degenerate into a surgical emergency. This situation is an example of how a cost-effective model can be used to evaluate 30 to 40 teams (management instances) within a 2-hour period during a race. A model was created using styrofoam mannequin heads and tubing, materials easily obtained in a hardware store, and foam tape and ketchup packets (Figure 114-10). Based on the consensus opinion of experienced practitioners, this provided a convincing look and feel that were adequate for novice training.

FIGURE 114-9 A correct response is more important than an erroneous fast response. *(Courtesy NAEAR and MedWAR.)*

The setup cost was $4.60, and the materials could be reused for approximately $0.65 per use.[2,13]

Based on formal participant feedback from surveys following multiple events, MedWAR was perceived as enjoyable and having educational value. In 2010, objective evidence was collected showing that participation improved medical performance and increased didactic knowledge. In one study, participants took a written test before and after the event.[16] Questions covered basic wilderness medicine topics; examination scores showed statistically significant improvement after the event, although pretest scores were high. A result more relevant to actual practice was demonstrated when participants were tested clinically.[24] A clinical scenario was created to test basic principles reinforced during a typical MedWAR event. The scenario contained 10 items considered to be critical actions, some of which had to be performed within a specified time to be considered complete. Actions were scored as "performed" or "not performed," and the scenario was timed from beginning to completion. A total of 34 teams were tested before the MedWAR event, and 31 teams completed a test after the event. The groups' pretest score was 71% of critical actions met (95% confidence interval [CI], 67.5% to 74.4%), and posttest score was 89.7% of critical actions met (95% CI, 86% to 93.3%). Mean improvement in postrace scenarios was 18.7% (n=31, 95% CI, 12.1% to 25.3%), with a significant paired two-tailed t-test ($p < 0.001$), showing that the race experience was effective in improving the number of postrace critical actions met.

As a form of standardized medical simulation, MedWAR events create an ideal setting to test an educational intervention. In 2012, two race organizers who were registered diagnostic medical sonographers wanted to evaluate novice providers' ability to learn from a brief on-line tutorial.[15] Few studies have examined the use of ultrasound (US) images to assist providers in making decisions about treatment and evacuation in wilderness settings. Participants in the 2012 Midwest MedWAR were asked to watch an on-line tutorial prior to the event. All participants received a unique log-in to allow accurate tracking of who watched the video. During the event, one medical challenge was presentation of US images of conditions that might be found in an austere setting and require interpretation. Of 72 study participants, 43 watched the training videos. Physicians (attending and resident) were significantly more likely to identify intraperitoneal fluid (89%) than were nonphysicians (64%), but the physician performance was not improved by watching the videos (89% vs 90%). Among the nonphysicians, those who watched the videos were significantly better at identifying intraperitoneal fluid (76% vs 47%). The results for identifying pneumothorax were similar but did not reach statistical significance. These findings suggest that for novice providers, an on-line training program followed by simulation testing provides a reasonable format for learning to interpret US images.

In 2012, the economic impact of a MedWAR event was assessed.[26] The demographics of MedWAR participants are more similar to those of a typically younger adventure race audience than to those of older, often better-funded physicians with a continuing medical education allowance. This economic study had value in estimating the impact of an event designed primarily for students. A survey of all volunteers and participants at the 2012 Midwest MedWAR was administered using questions modeled after a similar study. Most participants (44%) were receiving student loans; 39% had an annual income of between $20,000 and $60,000, with six participants reporting an income of over $80,000 annually. Participants traveled an average of 4.5 hours one way to come to the event, and 52 (58%) spent at least one night away from home, with nearly all camping in the host state park. Participants spent an average of $135 (range $20 to $385) on travel, food, and equipment independent of race entry fees and canoe rental. The registration cost was $135 per team of three. Each team was required to rent a canoe at a cost of $45. The estimated amount spent by a single participant on this event was $195, for a total of $20,475 for all 105 competitors. A dollar spent in a local economy translates into several dollars of total activity as some is spent, some saved, some taxed, and some exported. The spending multiplier formula is stated as

$$1/[\{1 - mpc * (1 - t)\} + mpm]$$

where *mpc* is the marginal propensity to consume, *t* is the income tax rate, and *mpm* is the marginal propensity to import. The local chamber of commerce placed the spending multiplier between 1.8 and 2.5 for this region, meaning that medical students, carpooling for half a day each way and camping during an adventure race, generated between $36,855 and $51,187 of economic benefit to the midwest region in this single weekend.

FIGURE 114-10 A and **B,** Midwest MedWAR: The clone army is an inexpensive reusable model for a surgical airway. *(Courtesy NAEAR and MedWAR.)*

SIMULATIONS, SCENARIOS, AND EDUCATION IN MedWAR

Simulation-based curriculum studies have shown measurable benefits.[29] In a study by Ten Eyck, participating students demonstrated improvement in learning and greater satisfaction with a simulation-based curriculum than with group discussion.[35] Simulation has been shown to improve students' ability to manage medical emergencies[4] and demonstrate competence in procedural skills and theoretical knowledge.[10,32] Although a study by Lo and associates revealed no difference in performance of advanced cardiac life support after a 1-year interval, students demonstrated greater knowledge initially using highly realistic simulation training compared with traditional training, and student satisfaction was higher when highly realistic training was used.[19]

Staging a good simulation requires setting the scene, choosing actors, applying makeup or moulage, and undertaking an appropriate evaluation after the simulation.[5] Most scenes in MedWAR are realistic because events are held in austere environments (Figure 114-11). Some details are occasionally stipulated, including the altitude, environmental conditions, distance from help, and availability of communication.

Teamwork is an integral part of medicine, regardless of the setting. Use of scenarios for drills and training in multiple and various settings are widespread. Simulation and scenarios have been used to evaluate and improve team performance in health care.[27,33,37] When scenarios require active student participation, group dynamics play a prominent role. Scenario-based education is easier if group members know each other. For example, search and rescue teams of long-standing membership or firefighting teams that run drills, work, and live together usually function well in their team roles. In a wilderness medicine setting, group dynamics form and evolve while people are on an expedition or trek. In a wilderness medicine *education* setting, participants often do not know one another, in which case the group must grow and develop. In 1965, Bruce Tuckman proposed the following model of group development.[36]

- FORMING: Limited interactions between individuals due to a need for acceptance and fear of conflict.
- STORMING: Different individual ideas are presented and compete. Leaders begin to emerge.
- NORMING: Team begins to come together and work as a team.
- PERFORMING: This stage describes high-performance teams; they do not require external supervision.

MedWAR planners address the issues of group dynamics by formation of self-selected teams prior to an event, which usually places them at least into the "norming" stage of development, and allows participants to focus on the tasks at hand rather than group dynamics and individual performances (Figure 114-12). The effectiveness of MedWAR simulations and scenarios may be enhanced by this preselection. The self-selection may allow a team member who is going to play a victim to let go of inhibitions and become a better actor.

Makeup and moulage may be difficult to provide when there are large numbers of race participants. However, many injuries and illnesses covered in the MedWAR curriculum (e.g., a fall with a head or cervical spine injury) do not require makeup. Efforts are made to make injuries look convincing, and appropriate props are also provided (Figure 114-13).

Medical equipment is an important part of the scenario performance. In MedWAR, each team is asked to bring the routine medical equipment they would take on an expedition to care for themselves or team members. The goal is for participants to

FIGURE 114-11 Southeast MedWAR: a simulated rescue helicopter crash. Participants had to care for the original patients that were being evacuated and then evaluate and treat victims of the simulated crash. *(Courtesy NAEAR and MedWAR.)*

FIGURE 114-12 Group dynamics and teamwork are accelerated and solidified. *(Courtesy NAEAR and MedWAR.)*

FIGURE 114-13 MedWAR North: another example of excellent moulage. *(Courtesy NAEAR and MedWAR.)*

FIGURE 114-14 Southeast MedWAR: immediate feedback is given by well-trained proctors. *(Courtesy NAEAR and MedWAR.)*

learn to use the equipment they have, with some component of improvisation.

Using critical actions enables the MedWAR staff to provide quality evaluation and immediate feedback. Proctors are trained on how to evaluate each critical action (Figure 114-14). Each noninvasive patient care action must be performed and not simply verbalized. Teams are expected to use the curriculum and anticipate what supplies they will need, thus providing their own material and equipment for each scenario. When possible, simulation equipment for invasive procedures is provided. Immediate feedback provides a memorable education event.

Stress is an important factor related to performance. Well-staged scenarios can be very stressful and emotionally powerful.[9] High-stress simulation training can help individuals learn to perform better in real-life stressful situations. Harvey and coworkers found that "in trainees, some aspects of performance and immediate recall appear to be impaired in complex clinical scenarios in which they exhibit elevated subjective and physiologic stress responses."[8] Highly realistic patient simulation produces significant stress. Müller and colleagues found that after 1 day of simulator training, the stress response as measured by salivary alpha-amylase was reduced. Clinical performance and nontechnical skills improved after 1 day of simulator training.[23] This intuitively correlates with many "inoculation" approaches to psychological stressors. The race aspect of MedWAR provides a sense of urgency similar to that of an urgent or emergent medical situation. The stress can be difficult to provide in other simulation settings where no time limitations or outside pressure exists.

CONCLUSION

MedWAR has been a highly successful program, incorporating wilderness medicine scenarios into an adventure race. This format provides a unique educational opportunity, accessible to many levels of health care providers and outdoor enthusiasts. MedWAR also provides a venue for innovative medical simulation models and for continuing medical education and simulation research.

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Complete references used in this text are available online at expertconsult.inkling.com.

CHAPTER 115

Evidence-Based Wilderness Medicine

CHRISTOPHER R. CARPENTER AND BRENT E. RUOFF

In wilderness adventures, initial medical management must often be provided in austere settings that are quite unlike highly controlled research settings that occur in academic hospitals. Nonetheless, in order to optimize outcomes, medical providers who deliver health care in wilderness settings should be cognizant of contemporary research that best reflects the clinical scenarios they routinely confront in the wilderness. Wilderness medicine provides a unique compendium of knowledge as evidenced by an increasing number of publications addressing adventure-related illness or injury, ongoing research, and distinct journals committed to this body of expertise. Wilderness medicine is more than just another library of facts, however. It relies upon robust individuals with a sixth sense about concepts that work versus those that fail, based upon personal experiences in this environment.[6] Understanding the terminology, concepts, and resources that underlie research-based medical practice can simultaneously ensure best-evidence "bedside" delivery and provide a framework for continuing to improve the science of wilderness medicine for future generations.[66] This chapter provides a roadmap for those who practice wilderness medicine to assimilate evidence-based medicine (EBM) principles into practice. It explores the roots and concepts underlying EBM and implementation science, explores common arguments against EBM, provides resources for wilderness medicine practitioners to employ EBM in heterogeneous settings, and highlights EBM using published wilderness medicine research.

WHAT EBM IS AND IS NOT

The term *evidence-based medicine* was coined in 1992 by Gordon Guyatt and the Evidence-Based Medicine Working Group as the overlap between clinician expertise, a patient's unique situation

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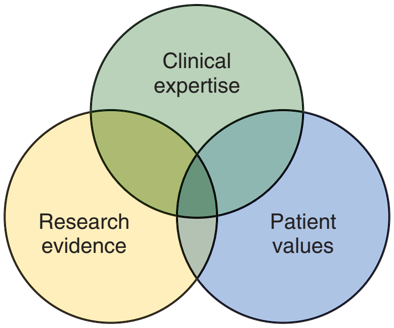


FIGURE 115-1 The EBM triad.

and personal values, and research evidence (Figure 115-1).[21] Although graduate education, resident training, and postresidency practice improvement (continuing medical education) have espoused the virtues of research evidence since the Flexner report of the early 20th century, this definition and concept of EBM provided a new approach to incorporating clinical research into bedside practice. For example, the process of EBM provided a template to seek, find, appraise, and apply research findings to individual patients, as opposed to the passive dissemination of research that had been relied upon by investigators, journal authors, and educators in the decades following the Flexner medical revolution.[23] Through a series of peer-reviewed "how to use and appraise" manuscripts published in the *Journal of the American Medical Association* (JAMA),[27] EBM proponents supplied a toolbox for learners at all levels of training to use research evidence appropriate for their unique practice settings. This *JAMA* series is now available as a textbook entitled *User's Guide to the Medical Literature*.[28]

A growing body of evidence suggests that clinical experience alone is insufficient to ensure that patients receive contemporary, guideline-based medical care.[14] Half of the patients in the United States do not receive evidence-based management in primary care.[46] Information overload is a substantial proportion of the problem. For example, emergency medicine providers need to read 26 articles in the *Annals of Emergency Medicine* to find one manuscript that changes their practice.[49] Because there are over 4000 biomedical publications that appear every day in PubMed, it is hardly surprising that busy clinicians frequently overlook new innovations and updated guidelines.

EBM is one approach to help overloaded clinicians find, evaluate, and use clinical research in their practice, but it is not a panacea. Malcolm Gladwell's novel *Outliers* provides examples of many talented individuals in a variety of professions, with each expert sharing one key exposure: 10,000 hours of mentored training to master their domain.[23] Most clinicians lack a high-quality, mentored exposure to EBM during their medical training[11,37] and there is ample evidence that traditional CME is ineffective at altering professional practice or improving patient outcomes.[22] Because it is unlikely that clinicians working long hours with increasing patient volumes and paperwork burdens will have the luxury of Gladwell's 10,000-hour exposure, EBM critics portray the EBM construct of finding, appraising, and using clinical evidence as an unrealistic expectation.[29,59,64] Some of the arguments of EBM opponents are noted in Box 115-1.[64] However, these same critics offer no viable alternatives to EBM,[39,45] and a fiscally fragile and increasingly strained health care system demands adaptation to progress and a focus on moving beyond the status quo.

BOX 115-1 Problems Inherent to the Philosophy of Evidence-Based Medicine

EBM grading is detached from scientific reality.
EBM proceeds where logical positivism failed.
EBM reduces scientific methodology to a single step.
EBM confuses statistics with science.
EBM lacks evidence of efficacy; hence it is internally inconsistent.

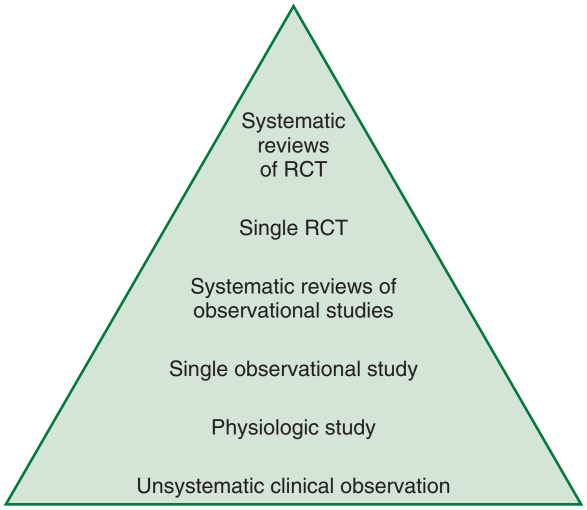


FIGURE 115-2 The EBM hierarchy of evidence.

THE EVIDENCE-BASED CLINICAL PRACTITIONER

Two key components of EBM are

1. Evidence alone is never enough.
2. Not all evidence is equally valid.

The first precept contends that there is an important and indispensable role for clinical expertise. Each clinician spends thousands of hours evaluating and contemplating myriad patient presentations and approaches to care. No textbook or journal manuscript will supplant this first-hand knowledge, which informs clinical intuition. In addition, patient priorities and values often trump clinical intuition and research evidence.

The second EBM precept refers to a hierarchy of research evidence. The hierarchy of evidence proposed by EBM leaders is depicted in Figure 115-2. In this hierarchical structure, systematic reviews and metaanalyses are considered the most accurate form of research evidence, followed by randomized controlled trials, metaanalyses of observational research, individual observational studies, case reports and case series, and bench research (e.g., physiologic studies), in order of the highest to lowest forms of clinical research evidence. The rationale for this hierarchy is that the highest forms of evidence are least likely to provide biased estimates of effect size, whether the research question is a therapy, diagnostic test, or prognostic factor. EBM proponents recognize that not every research question is amenable to a randomized controlled trial, so their emphasis is on ensuring the least biased estimate of effect size; hence the evidence hierarchy.

The evidence hierarchy can be illustrated using an example from wilderness medicine: frostbite. In 1978, Malhotra and colleagues used a rat model to assess the effect of bathwater temperature to treat frostbite.[44] Conclusions regarding the optimal water temperature were based on quantification of cold injury sustained on hind paws. On the EBM hierarchy of Figure 115-2, this physiologic study would represent a lower tier of evidence when extrapolated to humans.

In 2005, Twomey and associates evaluated tissue plasminogen activator (tPA) to treat severe frostbite. Twomey's experimental model assessed the lack of distal limb and digit perfusion using a technetium 99m (Tc-99m) bone scan. This case-control study used historical Tc-99m data from patients who ultimately required an amputation due to frostbite injury. Efficacy was evaluated by comparing the number of amputations in the patients treated with tPA with historical cohorts with amputations.[65] Compared with the Malhotra animal-model study, Twomey's data represent a higher level of evidence that is more applicable to human patients on whom this treatment would be applied. In other words, the case-control design is less likely to provide biased estimates of treatment efficacy than is the animal-based physiologic experiment, and can be applied to actual patients with more confidence, although case-control studies are far from definitive.

As described in detail in Chapter 9, significant evidence now exists to inform evidence-based rewarming and thawing of frostbitten extremities in humans, including wound management, intervention timing, severity assessment, and pharmacologic interventions with thrombolytics and antiinflammatory medications. The Wilderness Medical Society published frostbite management guidelines in 2011, updated in 2014, that provide a level of evidence rating for each recommendation.[47,48]

EVIDENCE-BASED MEDICINE: EXPERTS VERSUS PRACTITIONERS

Some commentators have stratified clinicians into EBM experts or evidence-based practitioners.[25] EBM experts seek to understand existing EBM principles, develop innovative EBM teaching modules or measurement instruments, and disseminate these ideas within and around the House of Medicine. On the other hand, evidence-based practitioners are less interested in EBM as a teachable concept and more invested in applying research evidence using EBM at the patient-provider interface. Many resources exist for individuals seeking to become EBM experts.[32,61] The focus of this chapter is on evidence-based practitioners.

The stepwise approach for evidence-based practitioners is depicted in Box 115-2 using the example of nonsterile water for wound irrigation.[67] The first step is to understand what information is required by asking an answerable question. The question is formulated using the PICO format:[15]

P = patient population
I = intervention (therapy, diagnostic test, prognostic factor)
C = control group (if applicable)
O = outcomes of interest

BOX 115-2 An Example of the Evidence-Based Medicine Process

Step 1: Derive the PICO Question

PICO Question:
Population: Patients with traumatic lacerations
Intervention: Tap water (TW) irrigation
Comparison: Sterile saline (SS) irrigation
Outcome: Wound infection, pain scores, cosmetic appearance, cost

Step 2: Devise a Search Strategy and Find the Evidence

Use PubMed to conduct your initial search using a combination of the search terms "wound irrigation," "laceration," and "drinking water," but find no citations, so you next try the combination of search terms "wound irrigation," "laceration," and "tap water," which identifies 10 articles (see tinyurl.com/WoundWater2016).

Step 3: Select the Least Biased Clinical Research Using the Evidence Hierarchy (Figure 115-2).

A Multicentre Comparison of Tap Water Versus Sterile Saline for Wound Irrigation, Acad Emerg Med 14:404-410, 2007 (pmid.us/17456554).

Step 4: Appraise the Evidence Using the Appropriate Critical Appraisal Worksheet (in This Case, the Metaanalysis Critical Appraisal Form From the User's Guide to the Medical Literature—Table, Figure, and Page Numbers Refer to the Original Manuscript in *Academic Emergency Medicine*).

Guide	Comments
I. Are the results valid?	
A. Did experimental and control groups begin the study with a similar prognosis (answer the questions posed below)?	
1. Were patients randomized?	Yes. "Subjects were randomized to SS or TW irrigation by opening the next numbered study envelope for that institution." (p 405)
2. Was randomization concealed (blinded)?	No. Subjects and treating clinicians knew the allocation arms. For this particular question, blinding subjects and clinicians would be impractical, though not impossible. For example, one could use tap water bottled in saline bottles as a sham.
3. Were patients analyzed in the groups to which they were randomized?	No clear intention-to-treat analysis is stated, although Figure 1 (p 406) suggests analysis within treatment arms.
4. Were patients in the treatment and control groups similar with respect to known prognostic factors?	The anatomic distribution (Table 1, p 407) and wound mechanism/length/repair did not differ between the two groups. No details are provided on patient factors (age, gender, race, time-to-repair, follow-up proportion) by which to gauge patient-specific confounding variables.
B. Did experimental and control groups retain a similar prognosis after the study started (answer the questions posed below)?	
1. Were patients aware of group allocation.?	Yes
2. Were clinicians aware of group allocation?	Yes
3. Were outcome assessors aware of group allocation?	No. "Providers in the emergency department (ED) removing staples or sutures were blinded to the subject's allocation." (p 405)
4. Was follow-up complete?	71/715 subjects were lost to follow-up (35 SS, 36 TW). Of those who were followed, 54% returned to the ED and 46% were contacted by phone!
II. What are the results (answer the questions posed below)?	
1. How large was the treatment effect?	634/715 eligible subjects were enrolled and analyzed. Most of those not analyzed were lost to follow-up (71). The SS infection rate was 3.3% (11 subjects), and the TW infection rate was 4% (12 subjects; difference 0.7% with 95% CI = –2.2% to 3.6%). Only one infection required admission. All others were managed on outpatient basis. Based on a patient charge of $9.11 for SS irrigation supplies, 13.5/L of water for 2 minutes TW irrigation at $0.0011/L (cost per patient $.0.0015) and $0.60 per 3 feet of tubing for 36% of TW patients ($0.22 per patient) the authors extrapolate a savings of $65.6 million/year in the United States if TW is used in place of SS. This savings is based upon the worst case scenario 3.6% increased infection risk in TW all treated with Keflex.
2. How precise was the estimate of the treatment effect?	Narrow CI for infection rate. The upper margin of 3.6% would not dissuade most from using TW instead of SS.

BOX 115-2 An Example of the Evidence-Based Medicine Process—cont'd

Guide	Comments
III. How can I apply the results to patient care (answer the questions posed below)?	
1. Were the study patients similar to my patient?	Yes. ED patients presenting to academic medical centers with acute lacerations.
2. Were all clinically important outcomes considered ?	No. The authors do not assess patient comfort or wound cosmetic appearance. Patient expectations may be an important, unmeasured impediment to routinely using TW rather than SS.
3. Are the likely treatment benefits worth the potential harm and costs?	Yes, TW appears to be equivalent to SS for acute traumatic laceration requiring emergency closure at a substantial cost savings.

Step 5: Summarize the Limitations of This Research and the Take-Home Message.

Limitations:

1. Unblinded (to patients and treating clinicians) convenience sampling. Because patients and clinicians were aware of allocation arm, bias (ascertainment bias, cointervention bias) is possible. In addition, convenience sampling could produce a selection bias.
2. Potential Hawthorne effect in the SS group because clinicians knew their patient outcomes were being monitored in a study setting. Did they irrigate longer, more carefully, or with greater volumes of saline than they otherwise would have?
3. Substantial lost to follow-up without any sensitivity analysis. Fortunately, equal numbers lost in SS and TW groups.
4. Nonvalidated telephone follow-up for 46% of those analyzed. Does anybody really think wound infection can be diagnosed over the phone as well as via face-to-face evaluation?
5. No statement of intention-to-treat analysis, although CONSORT diagram (Fig 1, p 406) suggests groups analyzed according to allocation assignment.
6. Underpowered study. Investigators calculated an *a priori* sample size of 1000 based upon a 10% infection rate. Doubling the observed 3.3% infection rate would recalculate a 1500-subject sample size. The current study only recruited 715 subjects (and only analyzed 634!), so they may have suffered a type I error (failed to detect a significant difference because of insufficient sample size).

Step 6: Determine Whether This Evidence Is Sufficient to Incorporate Into Your Practice.

Underpowered multicenter convenience sampling with substantial lost-to-follow-up and no sensitivity analysis suggests that TW may be equivalent to SS in uncomplicated traumatic lacerations requiring ED closure. If validated, these findings could simplify ED wound irrigation while saving $65.6 million/year in the United States alone.

SS, sterile saline; TW, tap water.

The PICO question is used to direct the search strategy that will acquire research evidence. Specific resources to find applicable evidence are discussed in the next section. Evidence-based practitioners prioritize evidence via the hierarchy of evidence (see Figure 115-2). The next step is to appraise the evidence. The User's Guide provides key questions for each type of research, including therapy, diagnosis, differential diagnosis, clinical decision rules, systematic reviews, harm, prognosis, and cost-effectiveness. Box 115-2 provides a real-life example of how evidence-based practitioners would use these principles to find the highest-quality research and then assess the risk of bias based upon the clinician's unique experience, patient population, and practice setting.

EVIDENCE-BASED MEDICINE RESOURCES FOR WILDERNESS MEDICINE PROVIDERS

A variety of free online resources exist to help physicians keep up to date on practice-changing or practice-enhancing research. Some of these resources are listed in Box 115-3. These products include synopses of journal club events across a variety of academic institutions. These often include reproducible PICO-based queries, critically appraised topics, associated podcasts, and social media feeds (e.g., Twitter and Facebook). Other resources, such as TheNNT.com, provide quantitative EBM reviews that may or may not be relevant to wilderness medicine but are searchable. In planning for a wilderness adventure, the content archived on these websites can be viewed as ready for educational sessions for wilderness providers to review.

In addition, free and unfiltered search engines exist for wilderness medicine providers with Internet access. PubMed (ncbi.nlm.nih.gov/pubmed) is commonly used and represents a medical librarian–archived resource made available by the National Library of Medicine. The PubMed website includes online tutorials to teach novice users how to optimize the search capability of this resource. As illustrated in Figure 115-3, PubMed Clinical Queries make up an extremely useful resource for clinicians to focus a search on therapy, prognosis, diagnostics, or clinical prediction guides.[1,41] Wilderness medicine providers can use Clinical Queries to quickly identify all of the research for a clinical question and then combine the findings with a search term such as "rural*" or "wilderness*" to isolate the most relevant studies for their setting (see Figure 115-3). PubMed also provides users with the capability to save search strategies and rerun them later. Some research indicates that physicians lack expertise in using PubMed and other search engines, so medical librarians are often quite helpful to enhance clinicians' capability to use these resources.[24,25] MEDLINE is another name for PubMed; OVID is a fee-based platform intended to add more user-friendly features to the PubMed search engine. Box 115-4 lists common terms used in evidence-based medicine; they may be helpful when doing searches.

Metaengines are electronic search products that simultaneously use medical terms to search PubMed, guidelines, textbooks, and other web-based resources. The TRIP database (tripdatabase.com/) is one prominent and free metaengine.[50] As demonstrated in Figure 115-4, TRIP provides the findings for a search

BOX 115-3 Free Evidence-Based Medicine Resources for Wilderness Medicine Providers

Search Engines
- PubMed: ncbi.nlm.nih.gov/pubmed
- TRIP: tripdatabase.com/

Journal Club Reviews
- Eastern Virginia Medical School: emjournalclub.com/
- Indiana University: http://emergency.medicine.iu.edu/research/ebm-journal-club/
- Temple University: templeem.com/blog/
- Washington University: http://emed.wustl.edu/education/EmergencyMedicineJournalClub

Quantitative Reviews
- TheNNT.com: thennt.com/

Statistical Calculators
- 2×2 contingency table: statpages.org/ctab2x2.html
- Posttest probability: dokterrutten.nl/collega/LRcalcul.html
- Sample size calculator: http://homepage.stat.uiowa.edu/~rlenth/Power

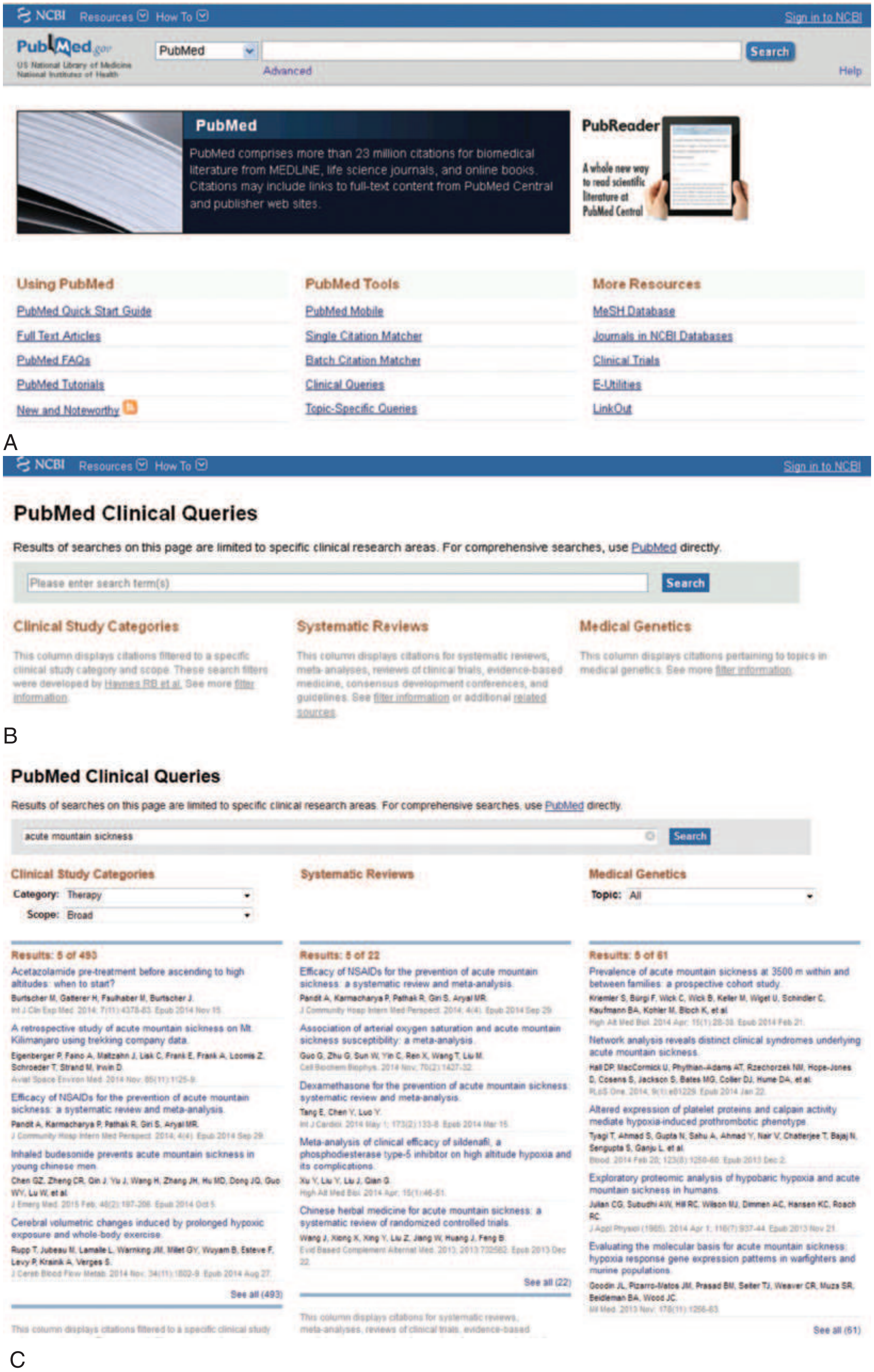
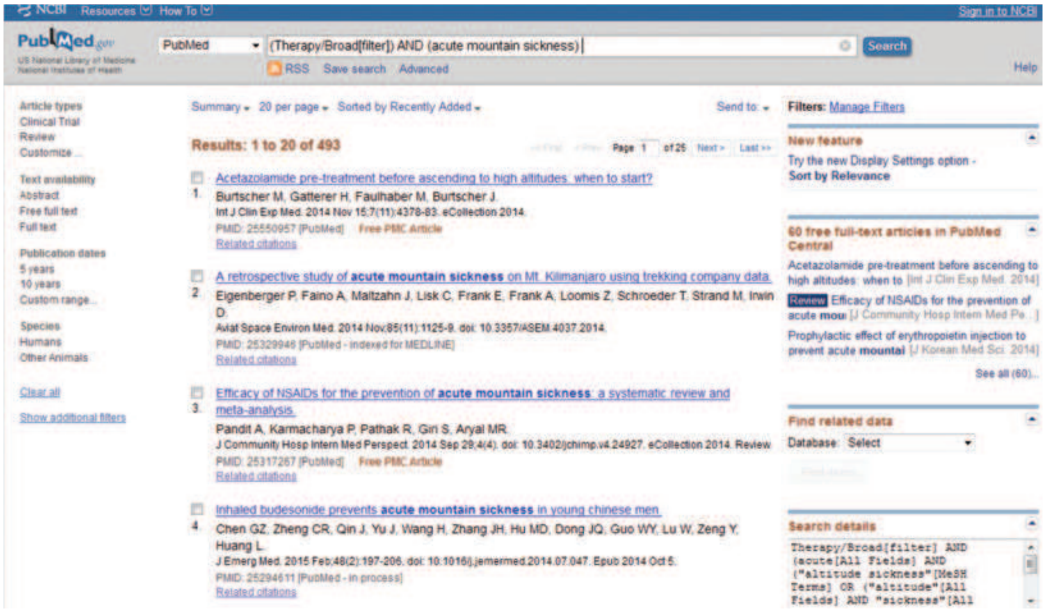


FIGURE 115-3 Free PubMed resources. **A,** Note PubMed QuickStart Guide and online tutorials, mobile applications, and clinical queries. Users can sign up for a National Center for Biotechnology Information (NCBI) account to save searches and receive email updates when relevant research is published based on established search strategies. **B,** Clinical Queries tab allows users to conduct broad or narrow searches for specific types of research. **C,** Sample Clinical Query of "acute mountain sickness" using the category "therapy" and "broad" scope. Other categories include etiology, prognosis, diagnosis, and clinical prediction guides. PubMed stratifies search results into clinical studies, systematic reviews, and medical genetics.



D

FIGURE 115-3, cont'd **D,** All of the PubMed citations under the Clinical Study category.

by listing the citations in the EBM hierarchy (see Figure 115-2). TRIP also allows users to save search strategies and can email users each month when new citations become available for a given search strategy or topic of interest.

Residency leaders in emergency medicine indicate that the primary skill set of EBM instructors ought to be the ability to identify secondary peer-reviewed resources for resident learners.[11] Secondary peer-reviewed literature is a snapshot synopsis of high-yield, practice-changing research with a critical appraisal already performed by a colleague in the field to which the research applies. Examples of secondary peer-reviewed resources include the journals *ACP Journal Club* and *Evidence-Based Medicine*.[30] The research summarized by secondary peer-reviewed journals undergoes a complicated process before reaching end-user bedside clinicians. In the case of *ACP Journal Club,* the McMaster Health Information Research Unit reviews 200 journals every month to identify higher-quality, minimally biased research methods. Once identified, these manuscripts are sent via email to at least three specialists in the applicable medical field(s), who rate the evidence for newsworthiness and likelihood of changing practice. The evidence that is rated by applicable medical specialties as both highly newsworthy and practice changing is then critically appraised with commentary by an EBM expert in that field. Wilderness medicine topics are included in these journals for conditions such as jellyfish stings[9] and tick bites,[51] but are quite rare. Developing a similar product is an opportunity for wilderness medicine organizations and journals. Secondary peer-reviewed journals are not free, but many offer complimentary services to "push" the most compelling evidence to the medical specialists affected by the new research. For example, KT-Plus (plus.mcmaster.ca/kt/Default.aspx) can be accessed by anyone who signs up for this service.[31]

Although most textbooks represent authoritarian dictate, narrative review, or unsubstantiated opinion, several textbooks exist that use the EBM approach described above.[53,58] In addition, journals such as the *Annals of Emergency Medicine,*[52] *Academic Emergency Medicine,*[13] the *Canadian Journal of Emergency Medicine,* and the *Journal of Emergency Medicine*[68] now publish EBM series regularly. As EBM interest and expertise grow in wilderness medicine, similar series could be developed for relevant wilderness journals. The disadvantage of these textbooks' and journals' EBM series is that a large proportion of contemporary wilderness medical practice has little evidentiary basis, or even worse, available evidence is contradictory.[35]

Clinical guidelines are another resource for health care providers, but these are often viewed with skepticism for a variety of reasons.[10] Guidelines are often outdated and do not exist for many of the clinical situations faced on a daily basis. In the future, guidelines should become more applicable and transparent as the Grading of Recommendations Assessment Development and

BOX 115-4 Terms Used in Evidence-Based Medicine

Bias: deviation from the "truth" (i.e., the correct effect size) observed in the study as a result of the research design, conduct, or reporting.

Critical appraisal: the process of assessing the risk of bias and applicability to one's patient population and clinical setting when evaluating medical research manuscripts.

D&I/KT: dissemination and implementation/knowledge translation science, which is the approach of applying evidence in the clinical environment with consideration of pragmatic challenges, reproducibility, sustainability, unintended consequences, and costs.

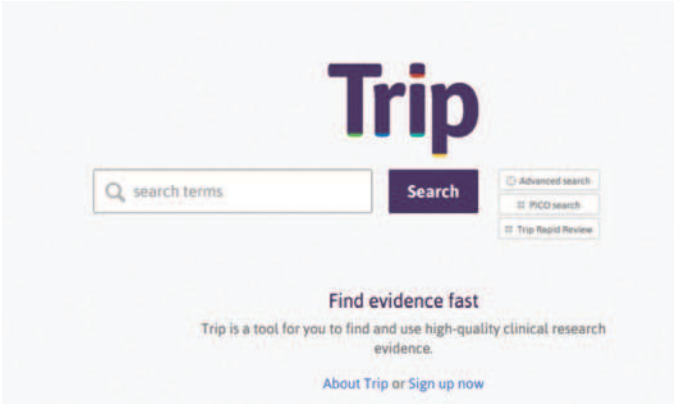
EBM: evidence-based medicine, or the philosophical approach of seeking the overlap of patient circumstances/values, clinical expertise, and research evidence to yield optimal outcomes.

Effect size: the quantifiable impact that an intervention has upon an intended (or unintended) outcome or measure. In the case of a therapy, the effect size is commonly expressed in terms of relative risk, absolute risk reduction, or number needed to treat and number needed to harm. On the other hand, in assessing a diagnostic test, the effect size is quantified using sensitivity, specificity, likelihood ratios, and receiver operator curve area under the curve. Understanding effect size empowers critical clinicians to (1) directly compare one intervention or test with another, and (2) communicate risk and benefit decisions with patients to facilitate shared decision making.

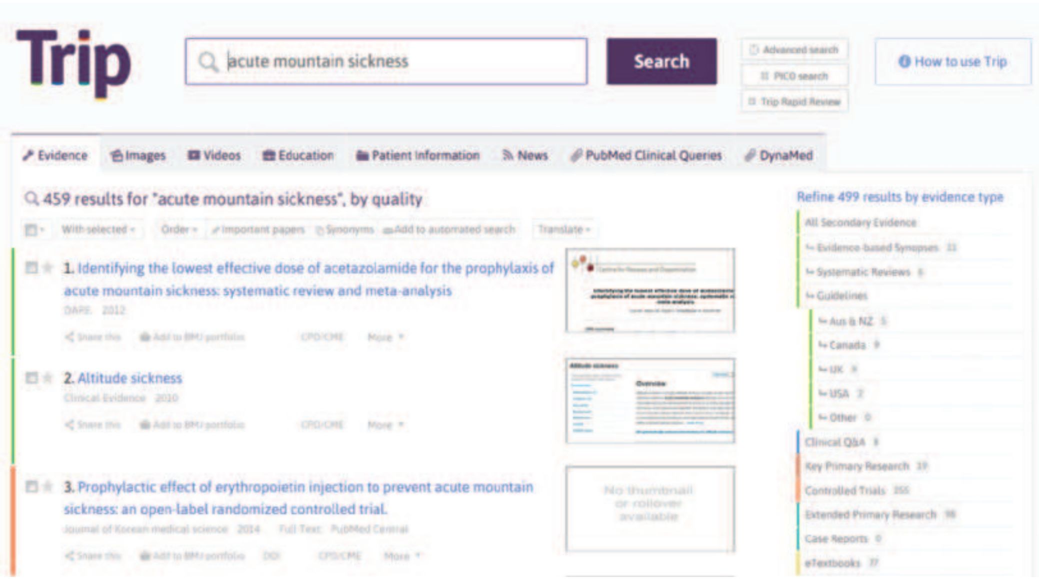
Metasearch engine: a software system that sends queries to several search engines or databases simultaneously.

Search engine: software system used to find evidence on the world-wide web.

Secondary peer-reviewed literature: journals or resources that provide critical appraisal and expert commentary about original research for other health care providers.



A



B

C

FIGURE 115-4 Free TRIP database resources. **A,** Enter search term. Note on the right that advanced and rapid search options are available, as is the possibility of constructing a PICO question upon which to base a search. **B,** TRIP search results for term *acute mountain sickness.* Note on the right that the results can be stratified by level of evidence using the hierarchy from Figure 115-2. Textbook chapters are included, and the findings most applicable to developing world settings can be identified with sensitive or specific filters. **C,** TRIP search results can also be stratified by “developing world” or “clinical area,” as observed on the right of this screenshot.

D

E

FIGURE 115-4, cont'd **D,** Using the PICO function to refine the search. **E,** PICO-refined search results. See tabs at top with images, videos, educational materials, patient information, and news.

Recommendation (GRADE) criteria are used to develop them.[26] As the number of guidelines for core wilderness medicine issues expands, wilderness medicine providers will need to be part of the guideline development process to ensure that the recommendations are pragmatic and attainable for this environment.[42] Wilderness medicine guidelines are appearing with increasing frequency for frostbite,[48] hypothermia,[70] heat-related illness,[40] spine immobilization,[57] wound management,[56] acute altitude illness,[43] exercise-induced hyponatremia,[4] and lightning injuries,[16] among others.

MOVING BEYOND EVIDENCE-BASED MEDICINE: WHAT IS IMPLEMENTATION SCIENCE?

Once clinicians find and appraise the evidence, it is necessary to apply the new information when treating patients. The original descriptors of EBM acknowledged this portion of the process, but the complexities were oversimplified. Over the last 10 years, a new science has been developed to explore and promote the process of applying the evidence. In the United States this process is called dissemination and implementation (D&I) science, and in Canada it is called knowledge translation.[7,38]

Why is there the need for D&I research? In the past, investigators assumed that publication of new discoveries was a sufficient dissemination strategy to promote practice change in applicable clinical settings, but diffusion of innovations is more complex in medicine, public health, and policy making.[5,8] In fact, the delay between biomedical scientific discovery and widespread implementation usually extends beyond 10 years.[2,3,18,55] The 2001 Institute of Medicine report entitled "Crossing the Quality Chasm: A New Health System for the 21st Century" noted a "chasm" between medical advances and current medical care.[33] For example, McGlynn and colleagues examined 439 quality indicators in adult primary care patients from 12 U.S. cities and reported that only 55% routinely received recommended medical management.[46] The National Institutes of Health (NIH) recognized as early as 2000 that effective translational science would require a paradigm shift.[71] Many barriers exist between scientific discovery and clinical application, ranging from the level of the individual clinician to that of the health care system. These include clinical awareness in an era of information overload, balancing healthy skepticism with sufficient evidence of effectiveness, misaligned incentives for evidence uptake and care delivery, and an evolving understanding of D&I research methods. A conceptual leak is loss of clinically used information. These leaks at the provider-patient interface are depicted in Figure 115-5, along with specific examples driving each leak and solutions to slow the relative loss.[19] By understanding these factors, evidence-based practitioners can more efficiently introduce high-quality, practice-worthy research evidence into wilderness medicine.

The complexity of D&I is in the questions that remain unanswered by the EBM process, including

- How is the "best evidence" defined against the spectrum of research findings, particularly when there exists conflicting evidence?
- How is "best evidence" efficiently disseminated (publication, opinion leader)?
- What is the effective component of the intervention?
- Can this effective component be replicated with fidelity in one's setting? If adaptation is necessary, when is the modified intervention sufficiently dissimilar from the published intervention that it is a different intervention?
- What organizational culture is essential to facilitate local adoption?
- Is the intervention sustainable?
- What are the unintended consequences of the intervention?
- What are the financial and personnel costs to implement the intervention?

D&I science is distinct from the traditional understanding of scientific discovery. D&I researchers often engage in systems engineering and behavioral modification, a process that usually engages stakeholders beyond the clinical setting and includes administrative leadership, social services, case managers, home health care services, and policy makers. In addition, most professions have been developing D&I methods, but the disparate nomenclature across nonmedical and medical fields is confusing and limits penetration of similar concepts.[54] Using D&I principles to speed adoption of appropriate evidence in wilderness medicine settings is an emerging concept.

THE FUTURE OF EVIDENCE-BASED MEDICINE AND DISSEMINATION AND IMPLEMENTATION IN WILDERNESS MEDICINE

Since 1992, the process of EBM has continued to evolve and improve.[36] More recently, D&I developed as a necessary and distinct by-product of EBM. EBM and D&I each depend upon the other to be most useful for health care providers, as well as patients and society. EBM and D&I will continue to evolve. One important advance is development of a reliable and accurate instrument to identify practice-changing or practice-enhancing research pertinent to one specialty: the BEEM rater tool.[12,69] This instrument provides a validated method to filter the signal from the noise amongst the 4000+ biomedical publications that appear on PubMed every day, and can be important for busy clinicians who lack the time to find, appraise, and assimilate all of these data. In fact, most published research is not ready for widespread application.[34] Figure 115-6 provides an example of how the BEEM rater tool could be used as a filter for wilderness medicine practitioners to find high-quality (i.e., minimally biased), practice-worthy evidence applicable to this unique health care setting. These methods could be modified to identify wilderness medicine–ready research evidence primed for widespread dissemination by developing a network of wilderness medicine research literature raters.

Adult learning theory emphasizes the process of learning that is problem based and collaborative rather than didactic. A substantial body of evidence implies that the traditional conference-based didactic instructor-to-learner one-way information exchange is ineffective to ensure quality improvement in medicine.[17,22] Another ongoing development in the EBM world is use of social media to promote a "bottoms-up" approach to disseminating high-quality research evidence. For example, the podcast "Skeptics Guide to Emergency Medicine" provides brief synopses of BEEM rater

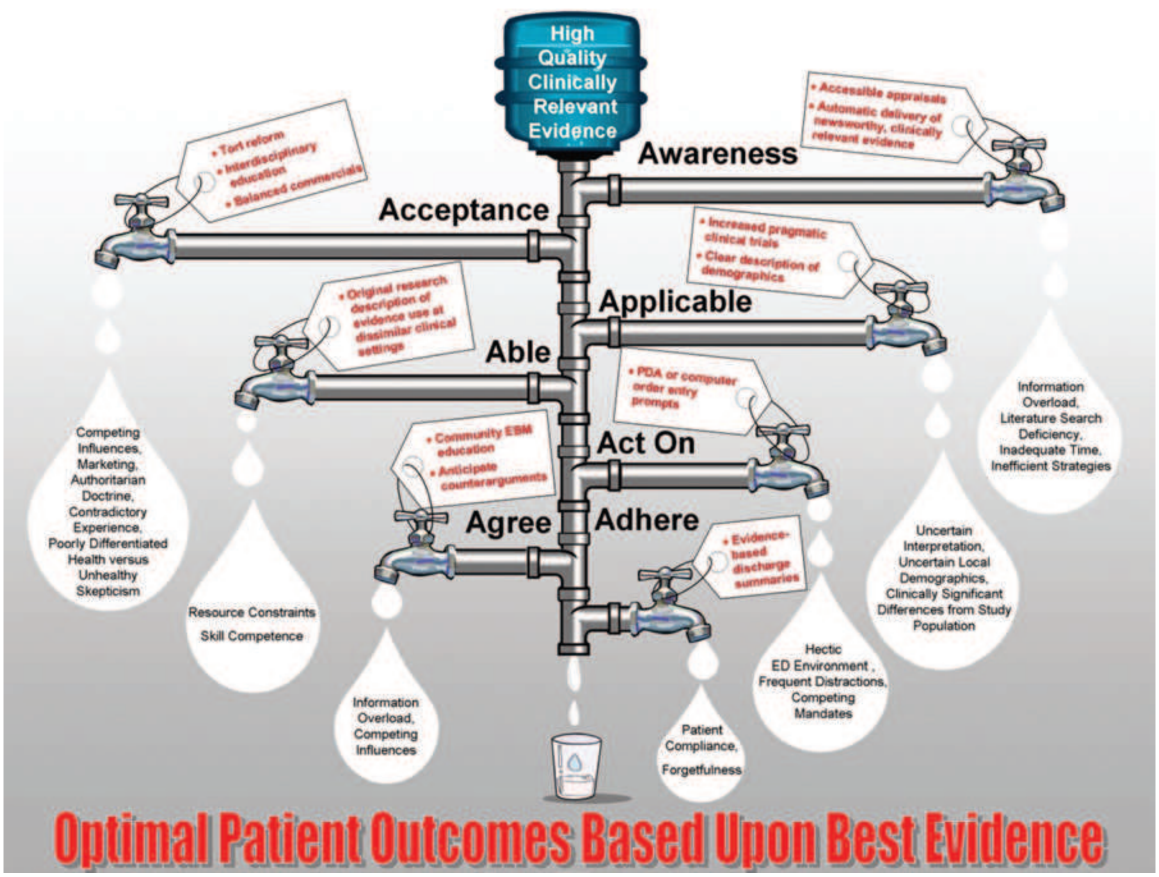


FIGURE 115-5 The knowledge translation pipeline. *(From Diner BM, Carpenter CR, O'Connell T, et al: Graduate medical education and Knowledge Translation: role models, information pipelines, and practice change thresholds. Acad Emerg Med 14(11):1008-1014, 2007.)*

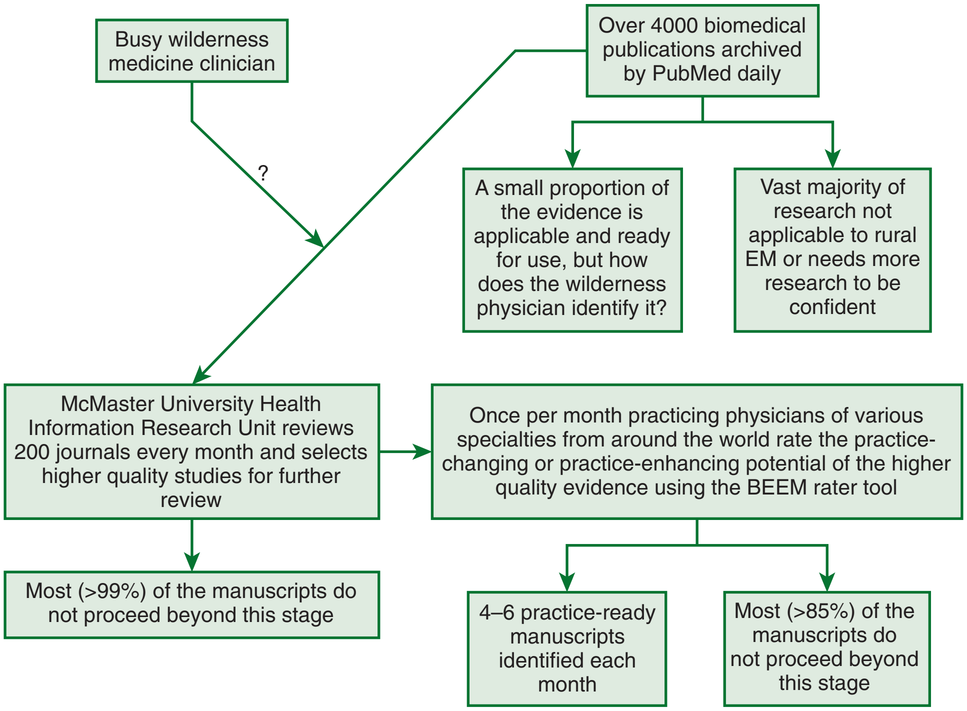


FIGURE 115-6 Potential application of the BEEM rater instrument.

tool–filtered evidence, targeting junior learners in an entertaining delivery mode using adult learning theory with the millennial audience in mind.[63] Other high-quality podcasts exist[20,60,62] and more could be developed for wilderness medicine aficionados.

CONCLUSION

Because of the austere environment in which wilderness injuries and illnesses occur, study of their prevention and acute treatment is quite challenging. Nonetheless, by using the principles of EBM, wilderness medicine providers can find, assess, and apply the most appropriate, least biased research to decision making in these scenarios. Furthermore, understanding the evolving concepts of implementation science provides wilderness medicine with a framework to move evidence to action and reduce unnecessary delays in translating evidence to wilderness care.

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Complete references used in this text are available online at expertconsult.inkling.com.

CHAPTER 116

National Park Service Medicine

SUSANNE J. SPANO

MISSION OF THE NATIONAL PARK SERVICE

The mission of the National Park Service (NPS) is to preserve natural and cultural resources for public enjoyment, education, and inspiration and to extend benefits of conservation throughout the United States and the world for future generations.[57] The mission is one century old. The NPS is responsible for both urban and wilderness areas. A brief history of national wild space conservation helps elucidate how emergency medical services (EMS) employed within the current park system have developed.

HISTORY OF THE NATIONAL PARK SERVICE

Although measures to preserve land for public use have been under way since the United States was founded, Congress did not create a unified federal agency to manage these areas until 1916.[7] In 1790, George Washington authorized for the first time that land should be reserved for the purpose of public enjoyment. This was in the District of Columbia, a planned city with a grand urban park system and parkways now known as the National Capital Parks.[14] In 1832, Congress created a precursor to modern

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national parks by setting aside four tracts of land surrounding Hot Springs, Arkansas, as the first federal reservation. This act was signed into law by President Andrew Jackson.[19]

President Lincoln used a federal land grant to preserve California's Yosemite Valley and the Mariposa Grove of Giant Sequoias. In 1864, these areas were ceded to the State of California to establish a state park.[49] In 1872, President Grant designated Yellowstone as the first national park. Because the park extended across borders of territories for which no governments existed, Yellowstone fell under federal jurisdiction.[15]

The next 44 years saw founding of the United States Forest Service, introduction of presidential authority to declare national monuments under the Antiquities Act under Theodore Roosevelt (1906), and founding of more than 39 national parks and monuments. Woodrow Wilson signed the National Park Service Organic Act in the summer of 1916.[54] The primary initial responsibility of the NPS was to protect wilderness resources. In 1933, Franklin D. Roosevelt issued an executive order consolidating sites previously managed by the Department of Agriculture and War Department within the NPS.[50] This order broadened the NPS mission to encompass the natural, historical, and cultural heritage of the United States in both urban and wilderness environments. The NPS currently administers 407 units, covering more than 84 million acres in 50 states, the District of Columbia, and U.S. territories.[10]

ORGANIZATION OF THE NATIONAL PARK SERVICE

The NPS is a bureau of the Department of the Interior, headquartered in the Washington Support Office in Washington, DC. The director of the NPS reports to the Secretary of the Interior, who in turn reports to the President of the United States. The NPS is organized into divisions (led by deputy chiefs) that oversee branches (led by branch chiefs). Awareness of the NPS organizational structure should inform interactions with the EMS leadership at a national, regional, or local level (Figure 116-1).[36]

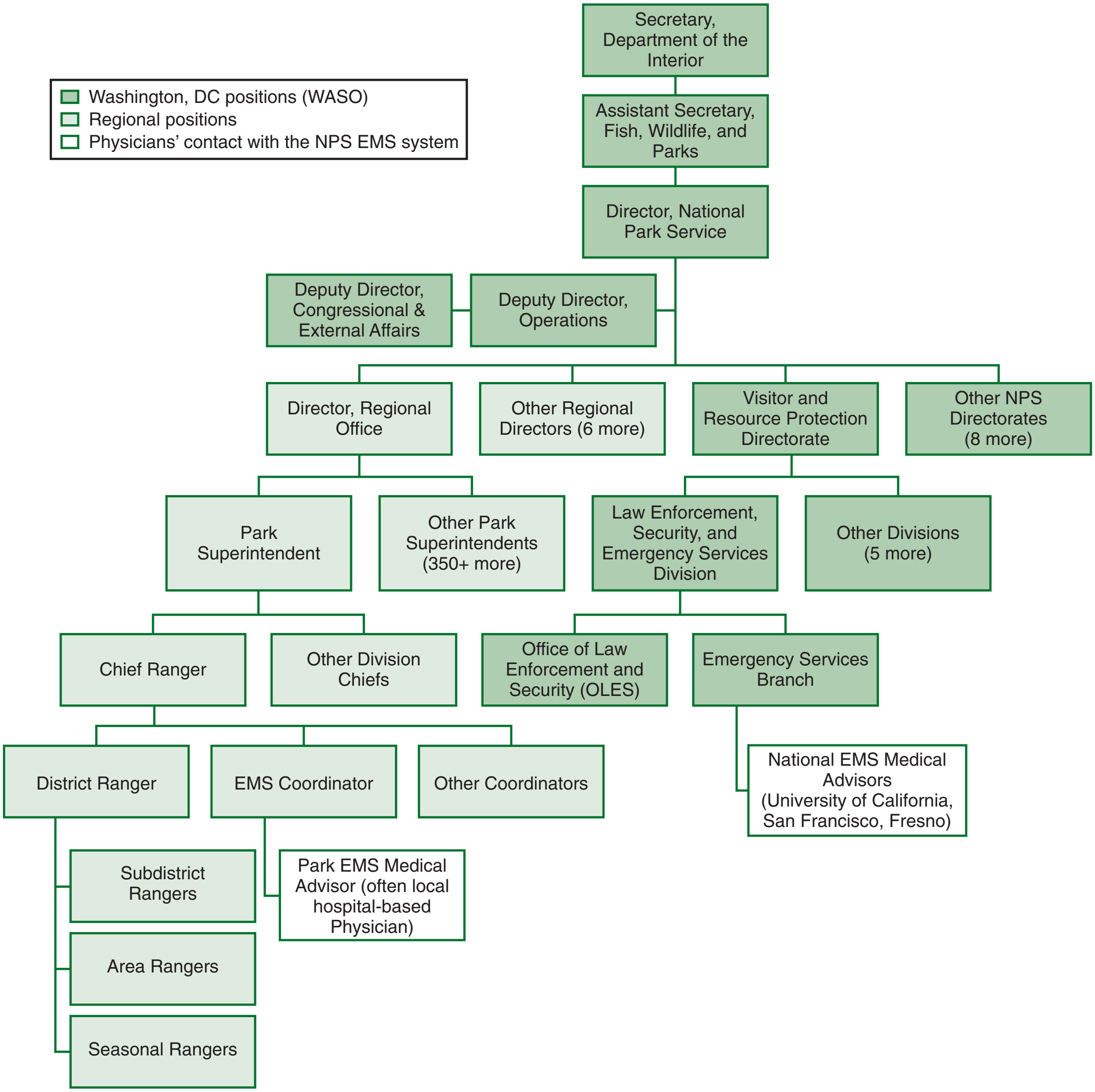

FIGURE 116-1 Organizational structure of the National Park Service. *(Redrawn from National Park Service Organization Chart, National Park Service Reference Manual 51 Version 1.0, University of California San Francisco Fresno Emergency Medicine public website: fresno.ucsf.edu/em/parkmedic/lema.html.)*

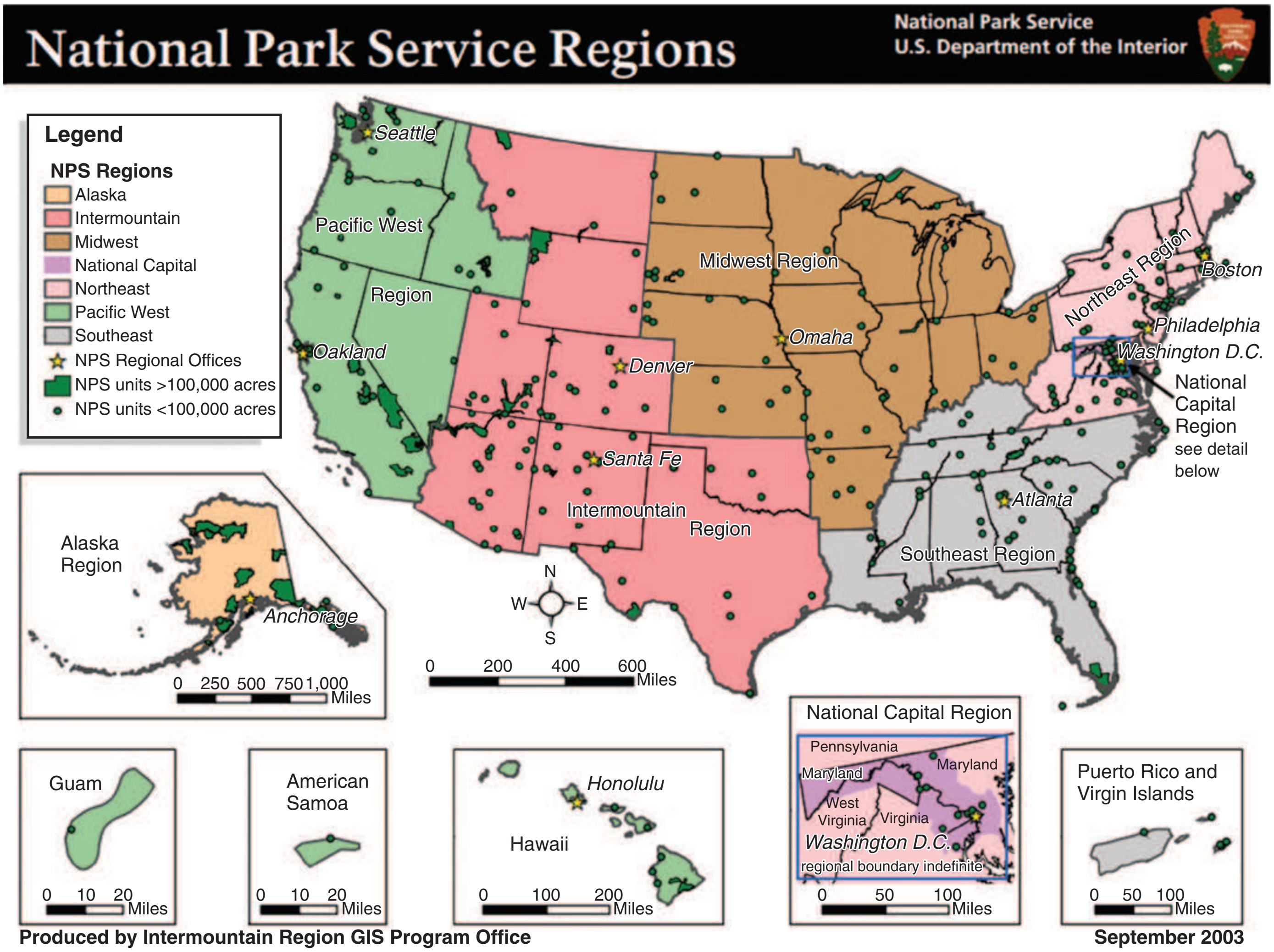

FIGURE 116-2 The seven National Park Service Regions include Alaska, Intermountain, Midwest, Northeast, Pacific West, National Capital, and Southeast Regional Offices. *(From map produced by Intermountain Region Geographic Information Systems Program Office:* nps.gov/gis/documents/nps_regions_11x8-5-new.pdf.*)*

The deputy director of operations for the NPS oversees nine directorates (business services; cultural resources, partnerships, and science; information resources; interpretation, education, and volunteers; natural resource stewardship and science; park planning, facilities, and lands; partnerships and civic engagement; visitor and resource protection; and workforce and inclusion) and seven geographically based offices for regional management of the parklands (Figure 116-2).[25]

The NPS directorate responsible for delivery of emergency services is the Visitor and Resource Protection Directorate. This office's associate director is responsible for the policies and oversight of the NPS EMS. The directorate issues a reference and field manual *(Reference Manual-51 [RM-51])* that details NPS protocols, procedures, and medications allowed to be administered.[38] This directorate is also responsible for other operations (e.g., fire and aviation management; office of public health; wilderness stewardship, and law enforcement, security, and emergency services [LESES] division).[44]

The branch of Emergency Services is based within the LESES division of the Washington Support Office. The Branch Chief of Emergency Services is responsible for managing NPS EMS programs. The Branch Chief is assisted by the national EMS Medical Advisor and the regional EMS coordinators of the seven NPS regions. The national EMS medical advisor is the physician(s) contracted by the NPS to provide medical recommendations. Historically, this has been a member(s) of the core faculty in the Emergency Medicine Residency Program, University of California, San Francisco Fresno (UCSF Fresno).[31] Each regional EMS coordinator inventories EMS data (e.g., certification levels of prehospital providers, regional centralized drug caches, medical supplies) within his or her service region.[29] Their recommendations (e.g., on system-wide quality improvements or adjustments in the appropriate prehospital scope of practice for the NPS EMS) are made to the Branch Chief of Emergency Services.

Day-to-day management and funding of EMS programs resides at the park level. Each park superintendent designates an EMS coordinator. This is often a ranger with additional responsibilities. A licensed physician serves as park EMS medical advisor (PEMS-MA).[29] The EMS coordinator and PEMS-MA are jointly responsible for park operational issues. This includes designating the requirements and scopes of practice for NPS EMS providers (e.g., emergency medical technician [EMT], paramedic). It also includes activities (i.e., routine training, continuing education, and quality improvement) intrinsic to any EMS system.[31] Each park's superintendent is ultimately responsible to ensure that a park EMS program is in compliance with the NPS Director's Order #51 (which outlines the policies and standards of the EMS program) and Reference Manual 51 (RM-51).

DIRECTOR'S ORDER #51

The Organic Act of 1916 delegated responsibility for the welfare of persons within parks to the NPS.[54] Within NPS-serviced recreational areas, emergency medical care is provided to approximately 13,000 of 279 million annual visitors.[5]

Rangers have been trained in first aid since the first park's inception. As visitation rose and incidents increased, levels of medical training have increased in step. In the 1970s, guidelines outlining the scope of practice and NPS-specific training were developed. In the 1980s and 1990s, a reference manual, field manual, and training programs were established under a National Emergency Medical Service Guideline.[29] In 2005, the NPS Director's Order #51 was issued and provided a detailed interpretation of policies, delegating specific authorities and responsibilities, and establishing the Parkmedic Program. The order reads: "The purpose of this Director's Order (DO) is to set forth NPS policy and a procedural framework for providing EMS. The policies, procedures, and standards in this document are to be implemented uniformly throughout the NPS inclusive of the U.S. Park Police. The details for implementation may be found in RM-51 and the EMS Field Manual."[29]

DEVELOPING ADVANCED MEDICAL TRAINING FOR NATIONAL PARK SERVICE RANGERS

The first formal advanced medical training for rangers was started by American mountaineer Dr. Thomas Hornbein at the University of Washington in 1968.[8] Dr. Hornbein and his climbing partner Willi Unsoeld were members of the first American expedition on Mt Everest in 1963, climbing via the treacherous West Ridge route.[20] As a former ranger in Mt Rainer National Park and practicing anesthesiologist, Dr. Hornbein developed a 110-hour curriculum covering emergency resuscitation and winter survival skills; it was taught in the park's off-season (January to April).

In the 1970s, EMS in the United States and the NPS developed rapidly. EMT certification programs became available throughout the country. In 1972, the first NPS EMT course (100 hours long) was taught at Camp Lejeune Marine Corps Base in North Carolina.[51] When Navy corpsmen returned from the Vietnam War, they brought remote first-aid skills from the battlefield to the backcountry; 23 rangers graduated with skills that included delivering a baby, reducing bony dislocations, establishing intravenous access, and administering medications.

The NPS Parkmedic Program developed in response to a 1976 accident, the Lost Soldier Cave Incident, in California. This Sequoia and Kings Canyon (SEKI) rescue of a spelunker with severe orthopedic injuries involved more than 18 persons, including a nurse, medical technician, volunteer climbers, four park rangers, and anesthesiologist (Dr. Harold Jakes), who served as an informal advisor to SEKI rangers.[8] The 22-hour rescue involved extrication of the immobilized victim through tight, twisting passageways and would not have been possible without pain medications administered by the registered nurse under direct physician orders from Dr. Jakes.

This experience highlighted the need for wilderness-specific EMS training programs. Compared with urban environments, in which responses were measured in minutes, in wilderness settings patients could be with rescuers for hours to days. In addition to a broad scope of practice (i.e., the ability to administer medications and provide lifesaving procedures), wilderness EMS providers needed authority to follow protocols to continue to provide care if medical control was unavailable due to exigencies such as equipment failure, electrical interference from lightning storms, or geographic barriers such as caves and canyons. In 1977, a new Parkmedic Program was adopted by the emergency medicine residents at UCSF Fresno based on training started by Dr. Jakes with SEKI rangers.[51] This program trained local park rangers to be prepared to meet NPS needs. The program focused on prehospital interventions and effective triage.[22] In 1978, the first formal "January Course" of the Parkmedic Program at UCSF Fresno graduated 20 rangers from Yosemite and SEKI.

PARKMEDIC PROGRAM

The Parkmedic certification course and the national NPS EMS medical advisors are based at the UCSF Fresno Medical Education Program.[45] The program develops and updates a range of national resources, including the RM-51[38]; *NPS First-Responder Field Manual* as an attachment to RM-51[33]; *NPS Medical Advisor Handbook*[31]; *NPS Paramedic Manual*[37]; *NPS Tactical EMS Protocols and Procedures Manual (RM-51T)*,[39] an online text for the Parkmedic training course: "Wilderness EMS, A Text for the NPS EMS Provider"[43]; and online training modules for tactical medicine, dislocation reductions, and epinephrine administration.[35] Current versions have restricted access for use within the NPS Servicewide for EMS operations, training, and continuing education requirements. Prior versions are available for public education through the UCSF Fresno emergency medicine website.

Certification and Authorization of Providers

NPS providers must demonstrate skills through a certifying body and be authorized to perform EMS within the national park unit to which they are assigned. The park EMS coordinator designates the scope of practice based on park and PEMS-MA recommendations. The National Registry of Emergency Medical Technicians (NREMT) oversees certification for levels other than basic training. Since 1970, the NREMT has administered a progressive process of EMS training, skills examination, and registration.[42] Six federal classifications (I to VI) are used to describe NPS prehospital care provider training levels.[40] Table 116-1 shows NPS EMS training levels and current recertification requirements.

TABLE 116-1 Emergency Medical Services Training Levels Available Within the National Park Service

NPS Levels of EMS Training	Description	Hours	Training Mandates
Level I	CPR/AED provider: minimum level recommended for all NPS employees	10	Recertify every year
Level II	Basic first-aid provider: for those not normally involved in visitor contract duties but who may on occasion be confronted with having to provide initial medical care	8	Recertify every 3 years
Level III	Emergency medical responder (EMR): appropriate for fire suppression, search and rescue, and backcountry operations	50	Recertify every 2 years; 12-hour review course; 4-hour CPR refresher
Level IV	Emergency medical technician (EMT)	114	Recertify every 2 years; 24-hour BLS refresher course; 48-hours of CME
Level V	Advanced emergency medical technician (AEMT) *or* Parkmedic: requires current CPR certification and minimum of 1 year of EMT experience	340	Recertify every 2 years; 36-hour ALS refresher course; 36 hours of CME
Level VI	Paramedic: requires current CPR certification and current EMT certification	1000	Recertify every 2 years; 48-hour ALS refresher course; 24 hours of CME

AED, automated external defibrillator; ALS, advanced life support; BLS, basic life support; CME, continuing medical education; CPR, cardiopulmonary resuscitation; EMS, emergency medical service; NPS, National Park Service.
Adapted from National Park Service Training Mandates, edition 04/03/2003: nps.gov/training/mandated-training-list.doc.

BOX 116-1 Parkmedic Protocols

Adult Protocols
Abdominal pain
Allergic reactions
Altered mental status
Altitude illness
Altitude illness prophylaxis
Bites and stings
Burns
Cardiac arrest or dysrhythmias
Chest pain, cardiac
Childbirth
Dystonic reactions
Electrical and lightning
Frostbite
General medical illness
Heat illness
Hypothermia
Ingestions, poisoning
Respiratory distress
Scuba dive injury
Seizures
Shock without trauma
Submersion injury
Trauma (eye trauma, isolated extremity trauma, major trauma, trauma arrest)
Vaginal bleeding

Pediatric Protocols
Cardiac arrest or dysrhythmia
Medical illness or fever
Newborn resuscitation
Pediatric medical parameters
Trauma (major trauma, trauma arrest)

Adapted from National Park Service Reference Manual #51 version: 01/01/2015 (internal), University of California San Francisco Fresno Collaborative Learning Environment.

The first two levels, I (cardiopulmonary resuscitation [CPR]/automated external defibrillation [AED] provider) and II (basic first-aid provider), are not NREMT certified. NREMT certification covers the next four training levels: III (emergency medical responder [EMR]), IV (emergency medical technician [EMT]), V (advanced emergency medical technician [AEMT]), and VI (paramedic). Parkmedics are certified at level V, which allows a unique scope of practice not recognized by the NREMT skills examination.

Parkmedic (Level V) Scope of Practice

The Parkmedic scope of practice is unique to the federal NPS system. It is determined by the level of training, the federal protocols, and the provider's extended scope of practice endorsed by the administrator of each park within its jurisdiction.

Parkmedic Training

Parkmedic program training occurs nationally at the UCSF Fresno Center for Medical Education and Research. A biennial 6-week certification course or a 4-week Parkmedic refresher and recertification course is taught in alternating years.[45] Successful completion of didactics, skills performance, and procedure logs is required for graduation. Providers gain clinic skills by engaging in patient care in the affiliated level 1 trauma center emergency department, EMS ride-along activities, and simulated procedures employing high-fidelity models. Written and skills examinations are required for certification. Parkmedics are certified as AEMTs, but their scope of practice exceeds that of AEMTs in several areas.

Protocols for Parkmedics

The *NPS EMS Field Manual for Parkmedics* (RM-51) details symptom-based protocol management, procedural descriptions, and medication administration.[38] The Parkmedic's expanded scope of practice (beyond that of AEMTs) includes advanced airway management (e.g., supraglottic airway tube, endotracheal tube, endotracheal tube introducer), needle thoracostomy, Taser dart removal, dislocation reductions, administration of additional intravenous medications, and a selective immobilization protocol that allows for decreased use of spinal motion restriction techniques.

NPS policy mandates that parks that will provide EMS at level IV or higher must implement the field manual standard protocols. This serves to ensure consistency of care and mitigates liability. NPS personnel transfer between parks during their careers. National protocols provide EMS uniformity despite transfers. Medical legal risks for physicians serving as medical advisors are also mitigated because standard protocols are nationally approved by the branch chief of emergency services and national medical advisor(s). Protocols are carefully vetted (sometimes at NPS EMS national conferences) before they are adopted. Ongoing feedback on current protocols from PEMS-MAs, rangers, and the Washington Support Office leadership is vital to modifying protocols as park needs change. In addition, a national NPS EMS advisory board composed of regional EMS coordinators, national medical advisors, and the branch chief of emergency services may convene to guide protocol revisions.

RM-51 protocols have two components: standing orders and base hospital communication failure orders. Standing orders have a stepwise structure. Step 1 is a reminder to assess a patient's airway, breathing, and circulation prior to any other steps. Step 2 highlights what pertinent findings should be sought in assessing patients within the protocol selected. Remaining standing orders systematically address field management of the presenting complaint. Communication failure orders (radio failure orders) outline procedures to follow if communication is lost between field and base hospital personnel, or when a radio connection cannot be established. These orders typically list procedural and/or medication administration recommendations relevant to the chosen protocol and can be enacted without a direct physician order. Box 116-1 lists RM-51 protocols.

All medications listed in the Parkmedic scope of practice are described in the RM-51 drug section (Box 116-2). Each medication description includes the scope of practice level (i.e.,

BOX 116-2 Medications Within the Scope of Practice for Parkmedics to Administer

Acetaminophen
Acetazolamide
Activated charcoal
Adenosine
Albuterol
Amiodarone
Aspirin
Atropine sulfate
Bacitracin ointment
Calcium gluconate
Cefazolin sodium
Dexamethasone
Dextrose 50%
Diltiazem
Diphenhydramine
Dopamine
Epinephrine
Erythromycin ophthalmic
Fentanyl
Glucagon
Glucose paste
Hydromorphone
Ibuprofen
Ipratropium
Magnesium sulfate
Midazolam
Morphine sulfate
Naloxone
Nifedipine
Nitroglycerine
Ondansetron
Oxytocin
Pralidoxime chloride
Sodium bicarbonate

Adapted from National Park Service Reference Manual #51 version: 01/01/2015 (internal), University of California San Francisco Fresno Collaborative Learning Environment.

EMT, Parkmedic, paramedic), medication class, mechanism of action, time to onset by route administered, duration of action, indications and contraindications, available formulations, age-appropriate dosing, additional notes, and cross-references to protocols that use the medication. An example is shown for acetaminophen (Figure 116-3).

RM-51 procedural protocols are formatted similarly (Box 116-3). For each procedure, absolute and relative indications and contraindications are listed. In addition, potential complications, equipment requirements, procedural steps, notes, and cross-references are presented. The scope of practice is the first line of the instructions. Some procedures (e.g., Gamow bag, King tube, nasogastric or orogastric tube) are listed as "per Local EMS Medical Advisor approved extended scope of practice" (i.e., the authority to determine the scope of practice resides within each park).

LOCAL CONTROL OF EXTENDED SCOPE OF PRACTICE

Decisions about which EMS training levels (I to VI) are to be deployed within an individual park are based on park needs, certifications of available rangers, and PEMS-MA recommendations.[31]

Acetaminophen (Tylenol)

Scope	EMT, Parkmedic, Paramedic.
Class	Antipyretic, analgesic.
Action	Elevates pain threshold and readjusts hypothalamic temperature-regulatory center.
Onset	PO/PR: 20 minutes.
Duration	4 hours.
Indications	Altitude illness. Febrile seizure. Fever. Mild pain.
Contraindications	Known hypersensitivity (rare).
Form	325 or 500 mg tablets. 160 mg/5 mL liquid.
Dosage	> 10–Adult: 1000 (975) mg PO every 4–6 hours. Do not exceed 4,000 mg in 24 hours. 0–10 yr: 15 mg/kg PO every 4–6 hours, max dose 1,000 mg. Do not exceed 4000 mg in 24 hours.
Notes	Small quantities of acetaminophen may be supplied to any person if requested for self-administration. The person should be offered an evaluation. A PCR does not need to be filled out if the person declines the evaluation and appears well. **REFERENCE PROCEDURE:** *When to Initiate a PCR (Patient Care Report/Run Sheet).* If the person appears acutely ill in your judgement, do your best to convince the person of the need for evaluation. A PCR shall be completed in this instance, even if the evaluation is declined. In general, acetaminophen and ibuprofen are interchangeable. The decision should be based on patient preference and contraindications.

Cross Reference

Procedures:	**Protocols:**	**Drugs:**
When to Initiate a PCR (Patient Care Report/Run Sheet)	Altitude Illness Bites and Stings Burns Childbirth Electrical and Lightning Injuries Eye Trauma Frostbite General Medical Illness – Adult Minor or Isolated Extremity Trauma Pediatric – Medical Illness/Fever Respiratory Distress Seizures Vaginal Bleeding	Ibuprofen (Motrin, Advil)

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Drugs 3000-P

FIGURE 116-3 Standard formatting for medications approved for use in the current Parkmedic manual. *(Adapted from National Park Service Reference Manual 51 version 01/01/2015 [internal] University of California San Francisco Fresno Collaborative Learning Environment [UCSF CLE]. www.fresno.ucsf.edu/em/parkmedic/downloads/lemadocs/ParkmedicProtocol.pdf.)*

BOX 116-3 Procedures Within the Scope of Practice of Parkmedics

Automated external defibrillation
Base contact criteria
Blood glucose determination
Capnography
Cardioversion defibrillation
Continuous positive airway pressure
Electronic control device dart removal
Endotracheal intubation
Endotracheal tube introducer
Epinephrine autoinjector
Foreign body airway obstruction
Fracture-dislocation
Gamow bag
Intraosseous access
Intravenous access and intravenous fluid administration
King tube
Mucosal atomizer device
Multicasualty incident reporting format
Nasogastric orogastric tube
Needle thoracostomy
Nerve agent antidote kit–Mark I
Oxygen administration
Pelvic stabilization
Rectal drug administration
Spine immobilization
Standard reporting format
Transcutaneous pacing
Transtracheal jet insufflation
Twelve-lead electrocardiogram
When to initiate a patient care record
Wound care

Adapted from National Park Service Reference Manual #51 version: 01/01/2015 (internal), University of California San Francisco Fresno Collaborative Learning Environment.

NEEDS ASSESSMENT

RM-51 policies help parks perform evaluations of the EMS program at least every 3 years through the "needs assessment" process. Needs assessment is used to evaluate EMS (versus contemporary standards) and to match the local EMS program size to operational needs. The volume and types of calls, transport times, and local and regional available resources are taken into account. Each park's needs are individually judged. A small park near a metropolitan EMS catchment area (e.g., Adams National Historic Park, Massachusetts) may require only that providers have basic life support response certification. A large remote park with a high visitation rate (e.g., Yellowstone National Park) will need a more sophisticated program. A needs assessment process creates an EMS plan to guide each park's EMS program.

LEVEL OF EMS TRAINING OF NATIONAL PARK SERVICE PROVIDERS

Required EMS training levels (I to VI) depend on identified needs, park resources, and the number of cardiac event EMS responses. The EMS plan requires input from the PEMS-MA for parks providing level IV to VI services. A key distinction between level V and VI prehospital EMS care is paramedics' more sophisticated approach to cardiac emergencies (e.g., advanced training in rhythm interpretation and cardiac medication administration).

Many parks do not use level VI providers (paramedics). Those that do have paramedic services often contract with local EMS systems. Mutual aid agreements to provide paramedic coverage may be subcontracted (by season or to a specified area of the park with high visitor density) as part of a larger EMS system. Subcontracted medics are not NPS personnel. The EMS Plan for Lake Mead National Recreational Area (in Nevada and Arizona) includes seasonal level VI service through a regional EMS system. Parks rarely employ rangers to act exclusively as level VI EMS providers. Most EMS rangers are also federal law enforcement officers. Several large parks (e.g., Yosemite, Yellowstone, Grand Canyon, and Lake Mead) have dual-role rangers who act as both law enforcement officers and level VI medics. Parkmedic (level V) certification offers sufficiently advanced medical interventions without paramedic (level VI) cost and training requirements.

PARK EMS MEDICAL ADVISOR ROLE

EMS providers are not independent practitioners. RM-51 standing orders reviewed and signed by a PEMS-MA provide the legal basis for EMS providers to perform procedures and administer medications. An EMS provider's prehospital services are considered to be an extension of the licensed physician who has signed the RM-51 standing orders. Without standing orders, a level V to VI EMT is only authorized to operate under the skill level of a level IV EMT, regardless of prior medical training. Medical advisors may create park-specific standing orders not listed in RM-51. Park-specific orders must be approved by the EMS Field Manual Review Board prior to use. New protocols, procedures, or drugs may be approved for local level use or added to RM-51. Each medical advisor may restrict the range of RM-51 standing orders for use in the park without need for review by the Washington Support Office.

Medical Oversight

The PEMS-MA assumes responsibilities analogous to an urban EMS system's medical director. PEMS-MAs provide medical control, including policy review, protocol development and incident reviews; maintain quality assurance and continuous quality improvement (CQI) processes; and provide continuing education and access to larger annual training events. Park EMS plans that provide automated external defibrillator service or level IV to VI services are required to have a PEMS-MA. Parks with level III programs are encouraged to have a PEMS-MA.

Medical Control

Medical control is both offline and online. Online medical control allows direct communication between a physician and an EMS provider to make real-time recommendations during patient care. This ability is ideal for advanced life support care delivery or when prolonged field times are encountered. An example of the importance of online control (i.e., via radio) was seen when a Sequoia National Park Parkmedic received medical advice while caring for a solo climber with a femoral fracture on a ledge on 14,000-foot Mt Tyndall. During this 53-hour rescue, the Parkmedic administered intravenous fluids and pain medications overnight while awaiting a National Guard Blackhawk helicopter evacuation.[56] Medical control from a provider with a strong background in prehospital care delivery is preferred. Hospital-based emergency physicians often serve as PEMS-MAs. A base hospital emergency department physician with local EMS base hospital certification can provide 24-hour online medical control. EMS providers communicate with a dedicated physician or mobile intensive care nurses familiar with Parkmedic procedures and protocols. Standing orders (i.e., offline medical control or radio failure orders) can help guide advanced life support care if online medical control cannot be established. Offline medical control includes review of RM-51 standing orders.

QUALITY ASSURANCE AND CONTINUING QUALITY IMPROVEMENT

Quality assurance and continuous quality improvement (CQI) are separate processes to confirm delivery of appropriate care and identify means to improve future care. In quality assurance, the EMS coordinator, EMS supervisor, and, as needed, PEMS-MA regularly audit each provider's patient care records. Any cases judged to put a provider at risk of disciplinary action are reviewed by the PEMS-MA.[31] The NPS uses a single electronic format patient care record developed by emsCharts. This allows national-level CQI analysis.[51]

The CQI process is used to evaluate each park's program. It has retrospective, concurrent, and prospective components. Retrospective CQI personnel review electronic patient care records to evaluate trends in care across providers.[16] For example, within SEKI there are approximately 300 to 350 annual EMS contacts and approximately 10 patient contacts per each level IV or V provider. This allows specific feedback to individual providers and enables evaluation of cohort trends. The concurrent CQI process describes quality improvement when care is actually being delivered.[17] This may be performed by a supervisor (or person at the level of EMS coordinator) observing care of a patient. The prospective CQI process targets areas for future improvement using continuing education.[18] Through systematic chart review and direct observation, EMS providers can receive regular feedback to reinforce successful care delivery and identify skills that may be improved.

CONTINUING EDUCATION

Continuing education is mandated to maintain NREMT certification, address educational gaps identified by CQI processes, and provide opportunities for group trainings in critical, but infrequently used, clinical skills (e.g., endotracheal intubation, intraosseous line placement). Continuing education schedules should include monthly sessions with interspersed time-intensive skill refreshers and drills.

REFRESHER COURSES FOR NREMT RECERTIFICATION

The National Registry does not specifically recognize the Parkmedic level of training. Parkmedics certified prior to 2013 recertify at the EMT-intermediate (I-85) level. Parkmedics who were certified more recently recertify at the AEMT level. Requirements for a level V provider are 36 hours of documented continuing education sessions and completion of a 36-hour advanced life support refresher course (see Table 116-1). As previously noted, a 4-week Parkmedic refresher course is held at UCSF Fresno biennially. Urban EMS advanced life support refresher courses also satisfy this requirement. Because level IV EMT refresher courses are shorter (24 hours), they are often conducted within local parks.

CONTINUING EDUCATION SESSIONS

Monthly sessions fulfill continuing education requirements for NREMT recertification and prospective CQI program needs. CQI data–driven topics review recent cases to increase awareness of the EMS provider's responsibilities. Each park's PEMS-MA conducts continuing education sessions, which typically last 3 to 4 hours each. The medical advisor's handbook[31] recommends that each session include 1 hour each for didactics, procedural practice, and quality improvement, with time allotted for questions and answers. NPS continuing education sessions can be held indoors or in natural environments as guided by didactic goals (Figure 116-4). See Figure 116-5 for a sample continuing education schedule for Parkmedic and EMT-basic providers.

MULTICASUALTY INCIDENT DRILLS

Many parks perform multicasualty incident drills to teach EMS providers triage policies and practices using the incident command system. RM-51 includes multicasualty incident triage algorithms and procedure protocols with checklists, assigned roles, and explicit responsibilities for reference. RM-51 contains triage algorithms, including simple triage and rapid treatment (START) and a pediatric algorithm known as JumpSTART.[21,48] These algorithms have been widely used in the United States since the 1980s, although little published literature has examined their effectiveness.[4] Simulations using these drills (e.g., tabletop scenarios, elaborate high-fidelity exercises) are effective teaching tools (Figure 116-6). Participants should be guided to consider how each simulation could improve future prehospital care encounters. A post hoc review of an NPS backcountry lightning multicasualty incident (with multiple adult and pediatric victims) found that triage tags were not used (not part of helicopter rescue equipment) despite decades of annual high-fidelity scenario training exercises, including with a triage algorithm and tag use. Despite this, an improvised on-scene triage method, while not

FIGURE 116-4 Sequoia and Kings Canyon National Park rangers participating in classroom-based continuing education. *(Courtesy Susanne J. Spano.)*

mirroring START/JumpSTART classifications, maintained rapid, appropriate evacuation priorities.[52] In addition to reviewing checklists and algorithms, drills should be designed to identify potential ways in which communications and care can be made more robust during future multicasualty incidents.

SPECIALIZED SUPPORT ASSETS

Specialized support services (e.g., air transport, technical rescue teams) are essential components to ensure that visitors are protected within the NPS. Specialized teams and equipment are available for local emergencies and nationwide deployment if required by a national crisis.

PERSONNEL AND NATIONAL RESPONSE

Each park ranger has multiple responsibilities within a park and must respond nationwide at the direction of the NPS director in event of an emergency.[3] Many full-time park rangers concurrently maintain training and certification in law enforcement, fire management, incident command system operations, search and rescue (SAR), and EMS. Additional training may be needed for some rangers in certain parks. Parks with large bodies of water may need rangers with scuba certification to maintain submerged cultural resources (e.g., Dry Tortugas National Park, Florida) and recover victims and wreckage from accidents (e.g., Isle Royale National Park, Michigan). Parks adjacent to international borders, or with large backcountry expanses, may benefit from tactical law enforcement teams, horse-mounted patrol rangers, and K9 units for law enforcement and lost person searches.

Park personnel may also request additional help from rescuers with technical rescue skills when a large response is needed. These technical rescuers can be found within the NPS or within community-based rescue organizations. In a request for mutual aid, park personnel may be temporarily reallocated to another park's jurisdiction when incident management requires such a move. Mutual aid responses enable a larger search effort than a single park could mount on its own. For example, the exhaustive search for veteran backcountry ranger Randy Morgenson in SEKI included 48 ground searchers, 4 helicopters, and 8 dog teams from park, military, and community SAR teams on just a single day.[2]

The NPS uses a 24/7 emergency incident communication center to report major incidents. The center (located in Shenandoah National Park, Virginia) expedites communications from field rangers to the director when a large coordinated response is needed.[30] The National Response Framework is the unified national response preplan for large-scale disasters and emergencies. NPS resources are a component of the National Response

Parkmedic CE Schedule 2008-2009

Meetings are at 9am. Two week schedule change notice can be given to Debbie Brenchley (EMS-C).

August 2008: Summer Break from CE

September 2008: Monday, September 29th
Topic: Chest Pain, Wounds, Eye injury, Lightning/Electrical
Procedures: Wound care, Combitube
Medications: Aspirin, Nitroglycerin, Neosporin Ophthalmic Ointment, Morphine
Resident Instructors: Drs. Schilling, Le, Kang

October 2008: Wednesday, October 8th
Topic: Allergic Reactions, Bites and Stings, Pediatrics
Procedures: Fracture dislocations, Epipen
Medications: Benadryl, Epinephrine, Morphine, Oxygen
Resident Instructors: Drs. Spano, Tsukamaki

November 2008: Monday, November 24th
Topic: Frostbite, Hypothermia, Burns, AMS
Procedures: Base Hospital Contact Criteria, Standard Reporting Format Accucheck
Medications: Bacitracin, Narcan, Glucose paste, Glucagon, Dextrose
Resident Instructors: Drs. Rubio, Urdanetta, Uranga

December 2008: Monday, December 9th
Topic: Abdominal pain, Cardiac Arrest, Childbirth
Procedures: AED, IV access, O_2 administration, Combitube, Delivery
Medications: Atropine, Epinephrine, Lidocaine, Bicarbonate, Oxytocin
Resident Instructors: Drs. Armenian, Caldwell, Eandi

January 2009: January Course

February 2009: Monday, February 23rd
Topic: Transport Decisions
Procedures: Intraosseous access, Rectal Drug administration, Transtracheal Jet Insufflation
Medications: Tylenol, Ibuprofen, Narcan, Glucose paste, Dextrose
Resident Instructors: Drs. Karaelias, Rodigin, Pham

March 2009: Monday, March 23rd
Topic: Ingestions / Poisoning / Seizures, Near Drowning
Procedures: Combitube, Epipen
Medications: Ipecac, Charcoal, Midazolam, Magnesium, Epinephrine
Resident Instructors: Drs. Ruegner, DeShields, Chacon-Lopez

April 2009: Monday, April 27th
Topic: GSW / booby traps, Trauma, Shock
Procedures: Fracture and dislocations, Dislocation reduction, Spine Immobilization, Needle thoracostomy
Medications: Ancef, Morphine, Reglan
Resident Instructors: Drs. James, Aggrewal, Hamilton

May 2009: Monday, May 25th
Topic: Altitude, Respiratory distress, Heat Illness
Procedures: Gamow bag
Medications: Nifedipine, Acetazolamide, Albuterol, Atrovent, Dexamethasone, Lasix
Resident Instructors: Drs. Schmitt, Chae, Kahwaji

June 2009: EMT REFRESHER

July 2009: MCI DRILL

FIGURE 116-5 Sample Parkmedic continuing education schedule for a park that has EMT and Parkmedic providers. *(Courtesy Susanne J. Spano and Ana Uranga.)*

Framework.[9] Preplan considerations include cataloguing qualified personnel, equipment, preexisting medical protocols, and communications plans that can operate between agencies and organizations at the local, state, or national level.

VOLUNTEERS-IN-PARKS PROGRAM

Former NPS Director George B. Hartzog, Jr., established the Volunteer-in-Parks (VIP) program in 1969, allowing the NPS to accept and use voluntary assistance from the public.[34] Anyone can be a VIP. Volunteer opportunities range from guiding interpretive programs to providing medical direction and emergency mountain rescue. Most PEMS-MAs are VIPs. Mountain rescue VIP positions are available in Denali National Park, Yosemite National Park, and Mt Rainier National Park.[6,11,26] VIPs are granted immunity from liability pursuant to the Federal Tort Claims Act.[55] If a negligence lawsuit is filed against a VIP, the United States is substituted as the defendant. VIP opportunities change often and can be found through the U.S. national volunteering site, through the NPS website, or by asking park personnel directly for information about them.[1,41] Volunteers are recognized for their efforts in donating more than 250 hours (free interagency pass), 500 hours (master volunteer ranger), and 4000 hours (presidential volunteer ranger) of service.[28] Volunteers have an enormous impact on the health and well-being of communities. According to the 2012 VIP report, 257,000 volunteers donated 6,784,971 hours, the equivalent of 3262 full-time employees.[32]

TECHNICAL RESCUES

Air operations and SAR teams are key specialized resources that complement an EMS plan. The NPS (e.g., Denali National Park, Alaska) uses advanced capabilities of fixed-wing and rotary aircraft and trained SAR technicians to save lives that might otherwise be lost.[8]

AIR OPERATIONS

The NPS has fixed-wing and rotary wing capabilities for carrying out park operations (i.e., EMS, law enforcement, and wildland fires management).[30] Given the prolonged transport times from remote national park locations to many level 1 trauma centers, parks may incorporate a neighboring EMS system's regional air ambulance services as part of their NPS EMS plan. Military aircraft can also be used for rescues because they typically have more robust operational abilities (e.g., can operate at higher altitudes, can carry heavier loads) than do civilian aircraft. In addition, military air operations are not subject to civilian flight restrictions (e.g., a ban on helicopter travel at night in mountainous terrain).[52] The U.S. Army National Guard and Reserve and U.S. Air Force Air National Guard units perform NPS rescues (e.g., Mt Denali, Mt Rainier, Yosemite, and Sequoia and Kings Canyon). Fire management is a large seasonal responsibility in larger western parks. Private helicopter services are often subcontracted (from May to October) for this purpose. In emergencies, these aircraft can be used to deliver personnel and supplies to remote areas of a park

FIGURE 116-6 Multicasualty incident drill triage practice in Sequoia and Kings Canyon National Park. *(Courtesy Susanne J. Spano.)*

FIGURE 116-7 Wildland fire helicopter H 1109, a rental helicopter from Inyo National Forest (Aérospatiale SA 315B Lama, not litter capable) used in Sequoia and Kings Canyon National Park. These helicopters are not designed for medical rescues and do not accommodate supine patients, even in emergencies. *(Courtesy Jason Bauwens.)*

for rescue operations. They are not configured as an air ambulance and may not be able to accommodate a supine patient (Figure 116-7). The NPS also supports a fleet of fixed-wing and rotary wing aircraft in Grand Canyon, Death Valley, Lake Mead, Glen Canyon, and Big Bend National Parks, and throughout Alaska.[30]

The NPS branch chief of search and rescue, Ken Phillips, developed the National Search and Rescue Academy training manual on helicopter rescue. It includes sections on hoist rescues, helicopter rappelling, and helicopter short hauls.[46] Hoisting involves lifting a victim attached to a rescue hook via a hoist cable. Helicopter rappelling allows a rescuer to be inserted into a rescue location. Short hauls use fixed lines directly under helicopters to move a rescuer or victim. Short hauls entail prolonged rescuer and victim exposures to environmental conditions but decrease the need for the helicopter pilot to maintain prolonged hovering close to unforgiving terrain. They also increase the haul-load weight capacity because the load is situated directly under the helicopter, which minimizes lateral forces. Load-bearing equipment designed specifically for helicopter rescue use includes rescue bags, collapsible baskets, nets, seats, trail lines, straps, and harness systems. To safely implement helicopter rescue teams, careful training is essential. Flight operations involve inherent risks that may be fatal to air crews not well versed in helicopter techniques.[12]

SEARCH AND RESCUE TEAMS

National parks provide opportunities for citizens to hike, bike, swim, climb, and spelunk and to travel cross country within vast stretches of wilderness. This leads to the need for SAR capabilities. NPS has been at the forefront of SAR training in wilderness settings.[8] Anthologies describing prior NPS SAR events include a rescue on Yosemite's Half Dome in a lightning storm, the search for lost Sequoia ranger Randy Morgenson, and park-specific reviews of accidental deaths in the national parks since their inception.[2,12,13,24]

SAR teams typically employ several specialized units (e.g., mountaineering unit, jeep unit, mounted patrol or "posse" unit, and rescue dog unit with trained dog and handler teams) acting in concert to contribute to the overall rescue effort. All team members are trained in wilderness SAR management and the incident command system.

Mountaineer units are the most commonly deployed search teams in backcountry settings. An effective mountaineer team has members proficient in swiftwater rescue, high-angle rescue, and ground-searching methods. Swiftwater rescue training may use rope rescue systems, swimming techniques, and rescue aids to reach difficult areas and approach dangerous swiftwater environments during both day and night conditions[47] (Figure 116-8). High-angle rescue requires specific training (e.g., in common knots, principles of rope systems, rigging physics) and regular

FIGURE 116-8 Swiftwater rescue training can include methods to safely transport an unresponsive victim in a paddleboat with minimal effort to the rescue crew. *(Courtesy Susanne J. Spano.)*

practice in order to establish safe anchors, belay systems, mainline lifting systems, and victim extraction techniques[27] (Figure 116-9). Ground-searching tactics enable teams to locate lost persons who are alert and signaling for help, as well as unresponsive victims or subjects intentionally evading search efforts.[23] Methods include mantracking, hasty searching (i.e., techniques that are rapid and cursory), and grid searches (i.e., systematic and time consuming). Mantracking techniques using tracking tools, measurements, and a trained eye to identify signs of recent movement through an area and can reliably mark every step a subject makes. Expert teams can track a lost person crossing manmade features, such as a road or bridge.[53] Each of these specialized areas is based on simple principles, but all require diligent practice because skills may deteriorate over time. Certification courses allow opportunities for rescuers to refresh skills.

FUTURE DIRECTIONS

National park medicine is increasingly focused on the role of prevention. New rescue tactics, innovative medical technology, and ultralight and durable outdoor gear will undoubtedly affect how rescue teams and victims interact in wilderness settings, but

FIGURE 116-9 High-angle rescue training in Sequoia and Kings Canyon National Park. Training may involve multiagency events with Parkmedics, NPS search and rescue teams, and local fire rescue members who may be part of a future search and rescue effort. *(Courtesy Susanne J. Spano.)*

preventive measures are essential to sustaining public enjoyment of backcountry spaces. Educational public outreach already occurs in many national parks. Preventive SAR efforts are still in their infancy. It continues to be difficult to design and conduct research studies to measure whether costs and suffering are reduced by educational programs. Full conversion to a uniform electronic patient care record will allow the NPS EMS to identify trends in a way not previously possible. In the last decades, the NPS has developed an efficient prehospital response system to rapidly respond to accidents. The charge of future leaders within the NPS EMS community is to develop public education tools (e.g., educational outreach, statistical analysis) for accident prevention.

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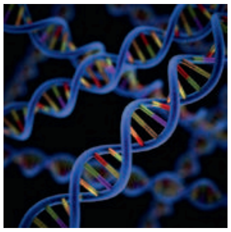

CHAPTER 117

Genomics in Wilderness Medicine

TATUM S. SIMONSON AND MARTIN J. MACINNIS

Human diseases involve disruptions in physiologic homeostasis. Genetic causes of disease are often explored by comparing cohorts of affected cases with unaffected controls or investigating inherited variations within families using linkage analysis. Diseases may be attributed to both genetic and environmental factors, and many (e.g., pulmonary hypertension, heart disease, cancer) are amenable to genetic research because they occur commonly with readily identifiable phenotypes. Similarly, some physical features (e.g., height or eye color) can be easily studied in a genetic context because they are common and stable over time.

Genetic studies on acute responses to environmental exposures (e.g., hypoxia, extremes of cold or heat, high levels of ultraviolet radiation) are more complicated. It may be difficult to standardize study conditions, identify proper "control" populations, and obtain appropriate sample sizes. Despite these limitations, genetic studies of wilderness-related diseases (based on individuals who have adapted to extreme conditions and those who have not) are currently under way. Many studies have focused on high-altitude adaptations, and others have explored responses to cold, ultraviolet radiation, and exercise.

GENETIC AND ENVIRONMENTAL INFLUENCES ON THE PHENOTYPE

According to the simplest explanation, *genetics* relates to the influence of the *genotype* (i.e., the sequence of the genome or a specific part of the genome) on the phenotype. A *phenotype* is the product of genetics and environment. The possible forms that a phenotype may take are called *traits* (Figure 117-1). Although the overwhelming majority of factors in the human genome are identical, numerous sites vary between individuals. These variable sites are referred to as *polymorphisms*. One category of variation is the *single nucleotide polymorphism* (SNP) or *single nucleotide variant* (SNV) (i.e., a single base pair that differs between individuals). Possible variants for a SNP/SNV are called *alleles* (or, more simply, genetic variants). Every human cell is diploid and so contains two copies of each *autosome;* therefore, each *locus* (position) in the genome has two alleles. These two alleles form the genotype at a particular locus (Figure 117-2). The genome guides the creation of proteins that carry out most biologic processes in our bodies. Alterations to the genome's nucleic acid sequence (e.g., alterations that influence structure, function, or expression of gene products, namely, proteins) can alter the phenotype.

If genetics describes the information in our genome, then *environment* refers to everything else. It may be easy to misconstrue environment to represent only our physical surroundings (i.e., altitude, cold, ultraviolet radiation); however, in the context of genetics, environment contains *all* of the external factors experienced by the organism (both abiotic and biotic). Genetics may be complex, but defining the effect of environment (in this broad context) on the phenotype is equally challenging. It is often the case that combined interactions between genetic and environmental factors ultimately create the variations in phenotypes.

Genetics is often used to explain the source of *variation* in phenotypes (i.e., to answer the question of whether individuals and populations are different because they differ genetically). To study the genetic basis of a phenotype in a population, that phenotype must vary (i.e., without phenotypic variation there are no phenotypic differences to explain).

Heritability is the ratio of genetic variance to total variance. Most genetic studies are interested in narrow-sense heritability (h^2), that is, the proportion of phenotypic variance attributable to *additive* genetic variance (i.e., variance from alleles whose contributions to the trait are independent of other alleles). This particular measure of heritability is used most often because it is related to the degree of resemblance between relatives.[246] The contribution of genetic and environmental variation to phenotypic variation is specific to the population under investigation. Even if genetic differences explain the majority of phenotypic variations in one population, environmental differences could explain the majority of phenotypic variations in another population.

As an example, imagine three human populations in which (1) everyone demonstrates an identical high tolerance of cold; (2) everyone demonstrates an identical low tolerance of cold; and (3) tolerance of cold is normally distributed (Figure 117-3). Genetics and environment unequivocally contribute to this phenotype. The question is whether *variation* in cold tolerance is due to genetic or environmental differences between individuals. The first two populations exhibit no variation. Whether genetic or environmental factors contribute more to a trait with nonexistent variation is moot. In contrast, there is considerable phenotypic variation in the third population. This population lends itself to the study of genetic versus environmental contributions to variation in cold tolerance. Variations in phenotype must exist for meaningful questions to be asked (e.g., Does a particular polymorphism explain the variation in cold tolerance, or do differences in diet explain the variation in cold tolerance?). Although

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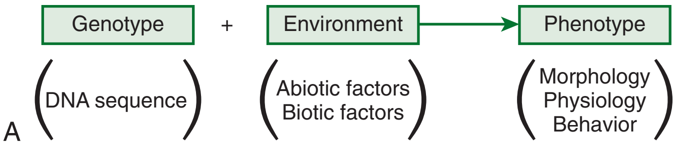


B

Phenotype	Qualitative traits	Quantitative traits
Eye color	Blue, green, brown, etc.	Density of pigment
Altitude tolerance	Low, moderate, high	Lake Louise Score
HIF1A gene expression	Increased, decreased	mRNA quantity
Enzyme activity	Increased, decreased	Enzyme activity

FIGURE 117-1 **A,** Relationship between genotype, environment, and phenotype. Subcategories are provided in parentheses below the boxes. **B,** Difference between a phenotype and a trait, and the difference between qualitative and quantitative traits. Note that a given phenotype can usually be examined in a qualitative or quantitative manner.

populations 1 and 2 are not very amenable to elucidating the role of genetic and environmental factors in isolation, they can be used to test hypotheses generated from studies performed in population 3. Alternatively, population 1 could be compared with population 2 to identify factors leading to their discrepant cold tolerances (although differences in ancestry and other potential confounding factors would have to be considered before drawing firm conclusions). For more in-depth discussion of heritability, see the article by Visscher.[246]

ESTABLISHING THE GENETIC BASIS OF A TRAIT

Many studies take advantage of greater genetic similarity between relatives versus nonrelatives to determine if genetics contributes substantially to phenotypic variation. This relationship applies to families as well as larger populations. Comparisons are made using twins, closely related family members, and biogeographic groups (Figure 117-4). See Bouchard and colleagues[35] for a comprehensive discussion of quantitative genetics (Figure 117-5).

Monozygotic (MZ) twins are genetically identical, so phenotypic differences between MZ twins should be entirely due to environmental factors. In contrast, dizygotic (DZ) twins share only approximately 50% of their genomes (the same proportion that nontwin siblings share), and differences within pairs of DZ twins will be due to both genetic and environmental variation. *Twin studies* compare variation between MZ and DZ twin pairs. Greater resemblance within MZ pairs than DZ pairs indicates that genetic differences explain some of the variation. In contrast, similar resemblances within MZ and DZ pairs indicate that genetic differences explain very little of the variation. For more in-depth discussions of twin studies, see publications by Martin,[151] Boomsma,[30] and MacLeod.[148]

Twin studies can be difficult to conduct without large registries, but family studies can be used to gather evidence for a possible genetic basis of a phenotype. Family members are

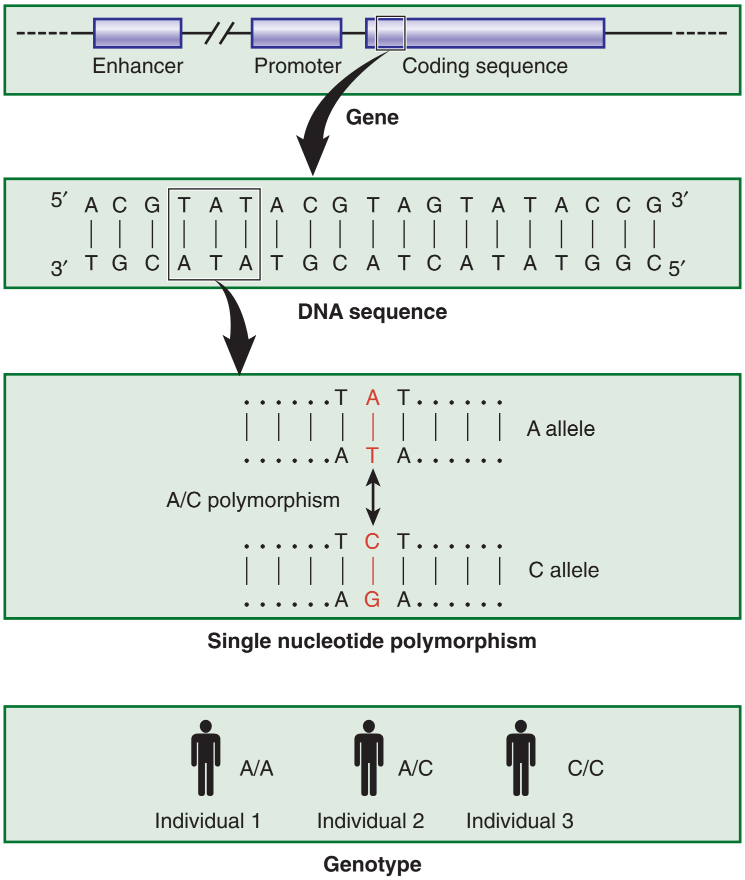
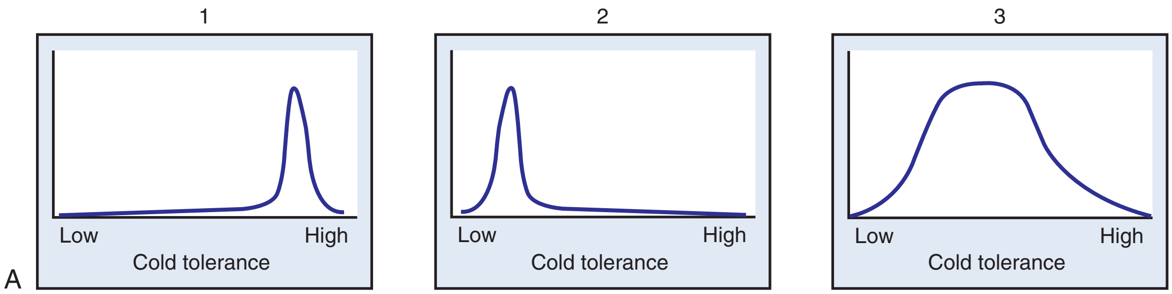


FIGURE 117-2 Schematic illustrating the hierarchy of genes, single nucleotide polymorphisms (SNPs), and alleles. Each individual's genome possesses the gene, but at the identified SNP, individuals possess two alleles (e.g., A or C), which may be the same (homozygous, A/A) or different (heterozygous, A/C).



B

Population	Phenotypic variation	Within-population comparisons	Between-population comparison
1	Low	No	Yes
2	Low	No	Yes
3	High	Yes	Possible*

* Although between-population comparisons are possible with this population, they are not necessary, and a within-population design is preferred.

FIGURE 117-3 **A,** Three populations with different distributions of cold tolerance. Population 1 has uniformly high cold tolerance; population 2 has uniformly low cold tolerance; and population 3 has a normally distributed cold tolerance. **B,** Information related to potential within- and between-population studies that could be designed. Only population 3 is suitable for within-population comparisons, whereas populations 1 and 2 could be compared with each other but are not suitable for a within-population study of cold tolerance.

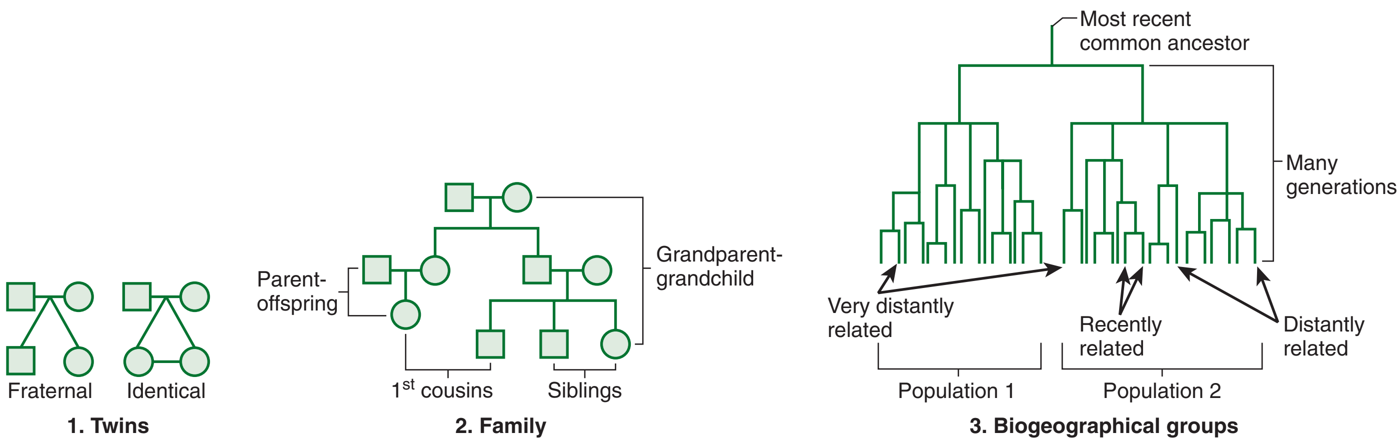


FIGURE 117-4 These schematics demonstrate the relatedness of fraternal and identical twins (*1*), family members (*2*), and distantly related populations (*3*). Pedigrees are not provided in biogeographical groups in order to illustrate the distant relationships that exist between any two populations.

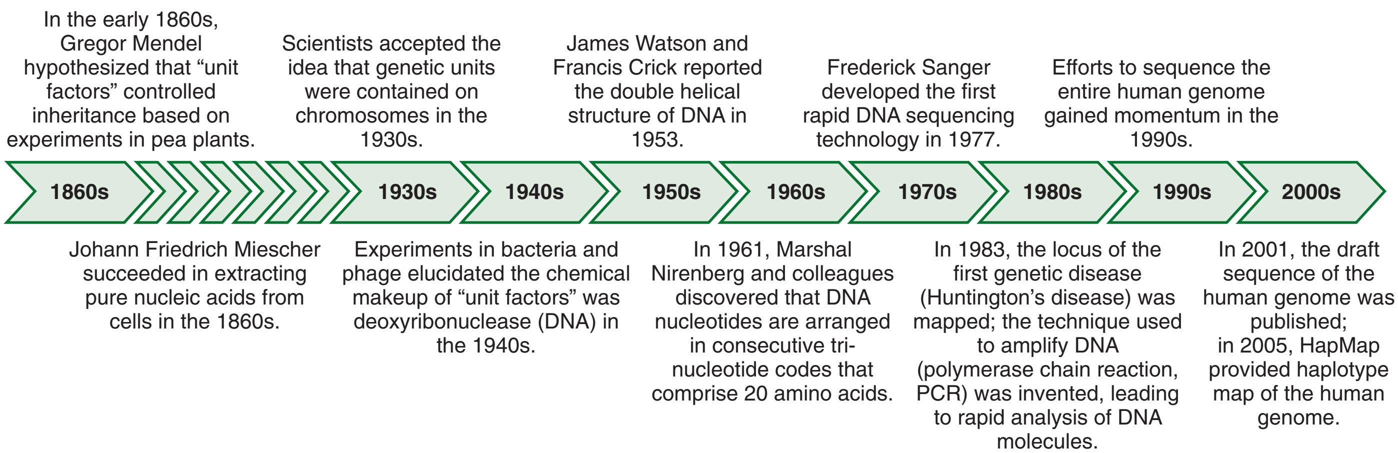


FIGURE 117-5 Progress in genetics and genomics from the 1860s to the 2000s.

related to different extents (i.e., sibling-sibling and parent-offspring pairs share approximately 50% of their genomes; grandparent-grandchild and half-siblings, 25%; and first cousins, 12.5%). Statistical models using family data can be employed to determine the extent to which a phenotype is genetic.[31] If a trait is observed to aggregate in families (i.e., it is more common within a family than within the general population), this can be evidence that genetic variation contributes to the trait. Because shared environments among family members could explain the clustering of the trait, familial aggregation is relatively low-quality evidence for heritability.[151]

Members of a biogeographic group are often more similar to each other than to outsiders. Individuals within a population are assumed to be at least distantly related to each other, but more closely related to each other than to members of separate populations. As is the case with familial aggregation, a difference in a trait's prevalence across populations supports (but is not proof of) an influence of genetic variation. Shared environments can also explain the clustering of traits.

Studies establishing the genetic basis of a trait are typically pursued prior to molecular investigations. Researchers should have sufficient evidence to support the hypothesis that genetic differences contribute significantly to the phenotypic variation before they explore how genetic variants contribute to phenotypic variation.

If there is a genetic cause for phenotypic variation, at least one polymorphism will be associated with that phenotype (although the strength of this association may be small). If the phenotype has only two traits (e.g., case and control), the two alleles will be distributed unequally; one allele will be more common in cases and the other allele in controls. If we use the cold tolerance example above, we might find that the C allele of the C450T polymorphism is overrepresented in persons with a high cold tolerance. We would say that the C450T polymorphism is associated with the cold tolerance phenotype: the C allele associated with high cold tolerance (a trait), and the T allele associated with low cold tolerance (a trait). "Associated" is used because this type of study is not a true experiment (i.e., the genetic constitution of an individual is not manipulated). Methods used to identify associations are described in the following sections.

THE ERA OF GENOMICS

Recent advances in genomics have provided unprecedented insight into human variation and its role in disease susceptibility. The vast amount of the coded sequence in the human genome makes up more than 3.3 billion nucleotides of deoxyribonucleic acid (DNA) in the form of adenine (A), thymine (T), guanine (G), and cytosine (C) bases (see Figure 117-2). This genetic alphabet is organized within 22 linear *autosomes* and two sex chromosomes (allosomes; X and Y) in the nucleus and a circular mitochondrial genome (≈16,569 nucleotides) located in the mitochondria organelle of the cell. Nearly all cells (with the exception of mature red blood cells) have two copies of each autosome, two sex chromosomes, and several thousand copies of the mitochondrial genome.

A history of genetics and genomics in medicine is provided in Figure 117-5. First drafts of the human genome sequence, published in 2001, revealed that a relatively small number of genes (20,000 to 25,000) are encoded in our DNA, and many genes have functions similar to those of other organisms (e.g., worms and flies).[124,244] This knowledge supported the use of nonhuman animal models in experiments designed to test functional relevance of human genotype-phenotype relationships (Figure 117-6). Technologic advancements continue to facilitate sequencing efforts, providing extraordinary amounts of information from many human genomes and various other species.

Less than 2% of the human genome encodes proteins. The sequence of these protein-coding genes is transcribed through production of complementary messenger RNAs (mRNAs) and transported to the cytoplasm for translation into proteins based on three-nucleotide codons that represent 20 distinct amino acids. A cell's total collection of transcribed RNA (i.e., mRNA, tRNA, rRNA, and a wide range of nonprotein coding functional RNAs) is called the *transcriptome* (see Omics Revolution, later). A cell's total collection of proteins present at one time is called the *proteome* (Figure 117-7). The number of copies of a protein is highly variable between cell types. An abundant level (≈ 50,000 copies) of nearly 2000 proteins suggests general biochemical "housekeeping" activities in most cells. The transcriptome and proteome of a cell (i.e., which RNA and proteins are expressed and the quantity of each that is present at a given time) are

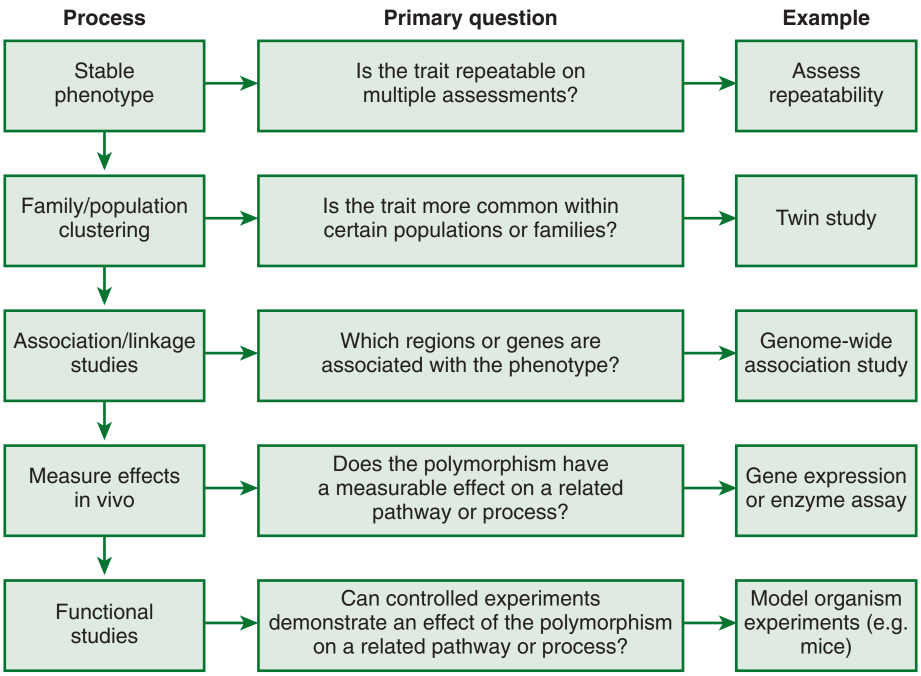


FIGURE 117-6 The typical process of determining whether variation in a particular phenotype is due to genetic variation. For each step in the process, the primary question posed at that step is provided, as well as an example of the type of analysis that would be performed.

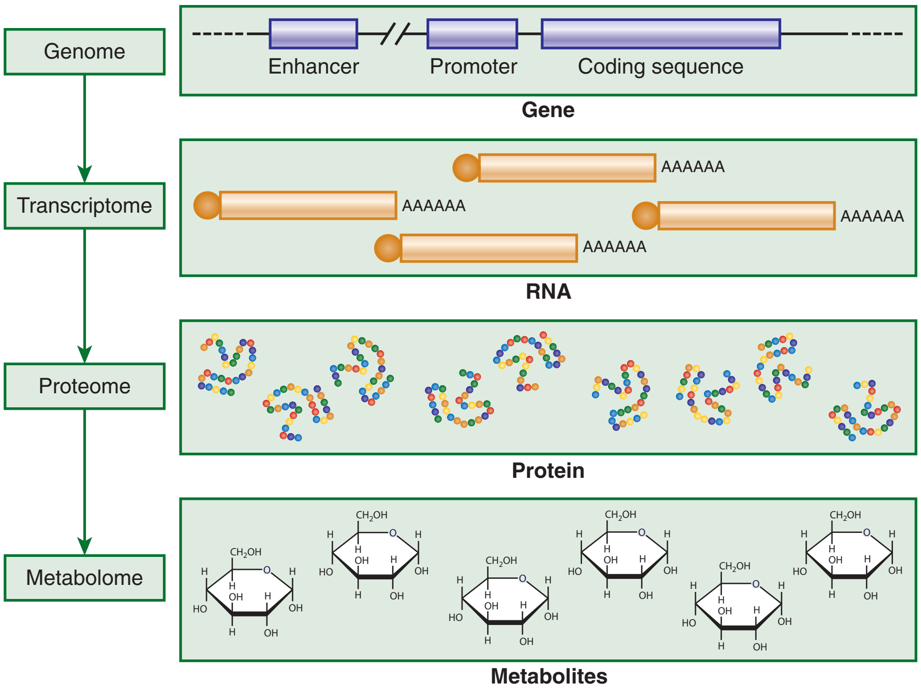


FIGURE 117-7 Hierarchy of the genome, transcriptome, proteome, and metabolome. The genome consists of genes and intervening sequences. The transcriptome consists of all RNA products transcribed from the genome. The proteome consists of all proteins produced from the transcriptome. The metabolome consists of all metabolites that accumulate in the cell, largely resulting from reactions and processes carried out by proteins. Note that the structure is hierarchical but that the lower levels can influence the upper levels. For example, metabolites could alter gene expression, which could modify the transcriptome, proteome, and metabolome.

determined by the genome in the context of the cell's development and the environment.

HUMAN GENETIC VARIATION

The International HapMap Project sequenced and catalogued SNPs in individuals of varying ethnic backgrounds so that common variations within human genomes could be studied. The initial SNP set included data from individuals of European, Yoruban African, Han Chinese, and Japanese descent.[107] The set was recently expanded to include individuals from more than 11 populations genotyped at more than 1.6 million SNP positions.[109] By showing that SNPs are generally inherited in large *haplotype* "blocks," this project granted insights into *linkage disequilibrium* in humans (i.e., by characterizing a small number of SNP signposts throughout the genome, insights into sequences of DNA are granted)[225] (Figure 117-8). Although the human genome contains more than 10 million common SNPs, characterization of only a subset (250,000 to 500,000) is required to "tag" the variation in human populations.[108]

Using low-cost, high-throughput genotyping methodologies, researchers can scan genomes of thousands of cases (i.e., individuals exhibiting a particular phenotype) and thousands of controls (i.e., individuals not exhibiting the phenotype of interest) to identify genomic regions associated with specific phenotypes. This method has been used to determine genetic links to various diseases (e.g., diabetes, psychiatric disorders, heart disease, and autoimmune disorders).

GENOME-WIDE ASSOCIATION STUDIES

The two primary study designs used to determine which genes and genetic variants are associated with a phenotype are *candidate-gene association studies*[55] and *genome-wide association studies* (GWASs).[97] In a candidate-gene association study, variants of a particular gene (i.e., the candidate) are chosen and tested for associations with a specific phenotype. For each individual, a phenotype is determined and a DNA sample is provided for genotyping. One or more polymorphisms from the candidate gene are selected and tested for statistical association with the phenotype. Because candidate-gene association studies only examine a very small region of the genome (1 of ≈ 25,000 genes), successful candidate-gene studies require strong hypotheses to select the genes most likely related to the phenotype.

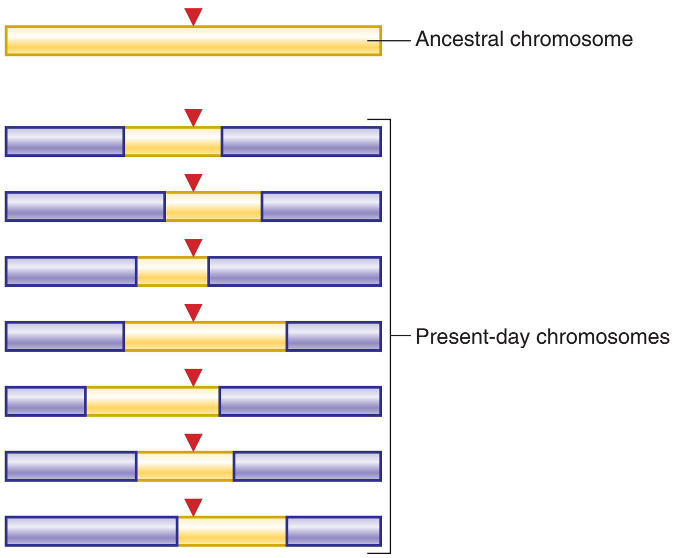


FIGURE 117-8 The mutation is indicated by a *red triangle.* Chromosomal stretches derived from the common ancestor of all mutant chromosomes are shown in *yellow,* and new stretches introduced by recombination are shown in *blue.* Markers that are physically close (that is, in the yellow regions of present-day chromosomes) tend to remain associated with the ancestral mutation, even as recombination limits the extent of the region of association over time. *(From Ardlie K, Kruglyak L, Seielstad M: Patterns of linkage disequilibrium in the human genome,* Nat Rev Genet *3:299-309, 2002.)*

In contrast, GWASs test for associations between the phenotype and 100,000 or more genetic variants dispersed throughout the genome. This approach is conceptually similar to simultaneously performing association studies across the genome. GWASs have a greater chance of testing the genetic variant associated with the phenotype, and no hypotheses for the genes involved are required. For these reasons, GWASs have obvious advantages over candidate-gene studies. Although small sample sizes can limit the statistical power of GWAS analyses (it is necessary to make statistical corrections to ensure a low probability of false-positive results), replication studies are often used to examine the original GWAS findings.

In contrast to rare diseases attributed to a variant in a single gene (e.g., cystic fibrosis), it was hypothesized that complex common diseases (e.g., heart disease) would be influenced by genetic variation spread across multiple genomic loci.[76] Despite extensive research, data on the influence of heritability for many common diseases are limited. Of more than 3500 SNPs linked to common diseases or traits, most underlie only small effects (1.2 to 2 times the population risk).[96] Although they are small in magnitude, these associations can provide useful information about a condition or physiologic process (Boxes 117-1 and 117-2).

Efforts to identify genotype-phenotype associations have recently turned to *whole-genome sequence* analysis. Similar to the SNP-based HapMap project, the 1000 Genomes Project was designed to catalogue *sequence* variations across different human populations. The initial 1000 Genomes data set was collected from mother-father-child trios and unrelated individuals from four diverse human populations.[74] This data set enabled researchers to classify variants beyond common polymorphisms and SNVs by providing information about less frequent DNA polymorphisms (e.g., insertions, deletions, and structural variants). The collection contains whole-genome sequence data from approximately 2500 individuals representing 25 populations. As genome sequencing costs fall, efforts to complete whole-genome sequence and *exome* (protein-coding sequence) analysis are increasingly feasible for research purposes and to link genotypes to phenotypes.[12]

OMICS REVOLUTION

SNP association studies and comparative sequence analyses provide an unprecedented amount of information, but questions remain regarding the functional relevance of genetic variants. The original *omics* discipline, genomics, has provided a scaffold for other large-scale omics endeavors to characterize genome-wide expression (i.e., transcriptomics), protein properties (i.e., proteomics), and metabolic properties (i.e., metabolomics) in a spatial- and temporal-specific manner. These technologies can help identify interactions, regulatory networks, and molecular functions and provide greater insight into genome function. This integrative approach is one branch of emerging research efforts, referred to as *systems biology* (see nature.com/reviews/focus/systemsbiology/editorial/index.html for more information).

Information regarding variation in gene expression across cells, tissues, individuals, and populations is currently being explored using approaches such as *RNA-seq*.[252] This technology provides the comprehensive sequence of every RNA molecule transcribed from DNA in a particular cell population (i.e., the transcriptome)[162,179] and can also provide important insight into epigenetic changes in cells.[113] *Epigenetic analyses* reflect changes that occur in gene expression above (epi) the DNA level as a result of heterochromatin states (i.e., tightly packed, limited transcriptional access) or euchromatin states (i.e., lightly packed, often transcribed access) of DNA (Figure 117-9). Epigenetic modifications change in response to environmental cues,[80] resulting in phenotypic plasticity,[67] and may be inherited across generations.

FUNCTIONAL GENOMIC ELEMENTS

Evidence indicates that a vast array of functional genomic elements are harbored outside the approximately 1.5% of DNA that codes for proteins.[124] Comparative mammalian sequence alignments indicate that approximately 5% of the human genome is under evolutionary constraint, exhibiting levels of conservation across taxa that are far greater than the genome average, suggestive of important biologic functions.[135] Recent studies suggest even higher percentages of constraint (4% to 11%) if protein-coding regions are excluded.[138,253] Analyses of nonprotein coding regions of the genome reveal sequences that regulate gene expression (i.e., functional *enhancers, silencers,* and *insulators*) and sites at which DNA's transcription into RNA is initiated (i.e., *promoters*). Genomic segments that encode RNA transcripts that are not translated into proteins but play important functional

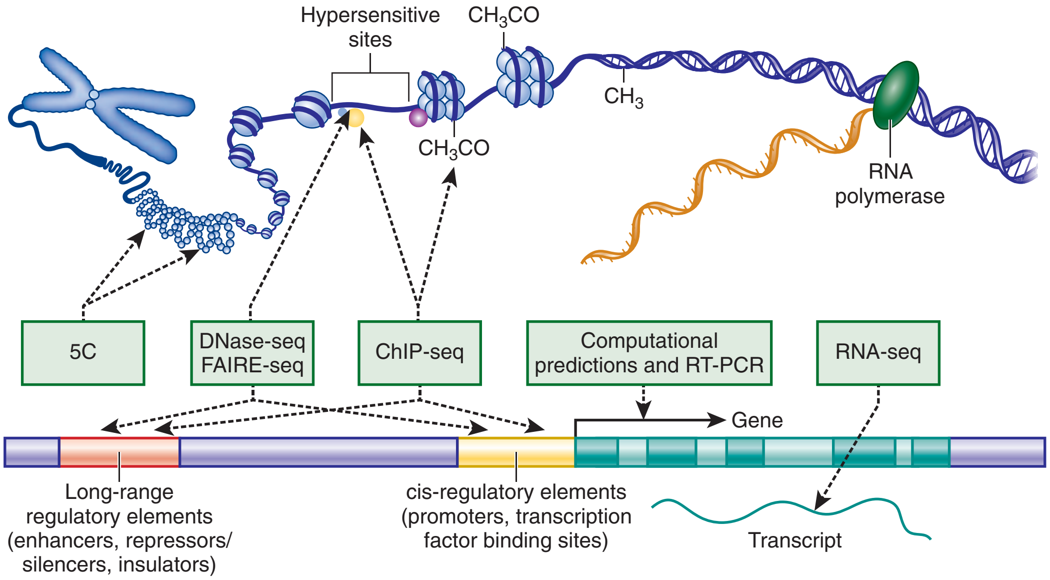


FIGURE 117-9 Diagram of ENCODE components. ENCODE aims to identify functional elements in the genome by annotating gene elements based on comparative genomics, bioinformatics, and comparative analyses. Regulatory elements are identified through assays that determine RNA sequence (indicative of gene expression), DNA hypersensitivity (open, eu-chromatin), DNA methylation, chromatin immunoprecipitation (ChIP), and ChIP-seq (to determine the sequence of protein-bound DNA elements). *(From Darryl Leja, National Human Genome Research Institute, and Ian Dunham, European Bioinformatics Institute: epigenomebrowser.org/encode.)*

BOX 117-1 Terms Used in Genomics

Term	Definition
Allele	One of two or more alternative forms of a gene that is found at the same place on a chromosome
Autosome	One of the 22 pairs of chromosomes not involved in the determination of sex
Candidate-gene association study	An approach that involves preselected genes or genetic variants of interest that are tested for relationships to phenotypes or disease states
Chromatin immunoprecipitation	Precipitation of a protein out of solution using an antibody specific to the chromatin mark of interest; this is used to assess interactions between proteins and DNA in the cell and provide information about gene regulation
Enhancer	A region of DNA to which activators (proteins that serve as transcription factors) bind and initiate transcription of a gene
Epigenetics	Reversible DNA or histone modifications that affect gene expression without altering the DNA sequence
Exome sequence	Protein coding portion of DNA sequence (< 2% in the human genome)
Genome	Complete genetic material of an organism; with respect to humans, the genome refers to the haploid set of chromosomes contained in the nucleus (the mitochondrial genome is considered separately)
Genome-wide association study	An approach that involves examination of genetic markers across the genomes of many people, with and without a particular phenotype or disease state, to test for relationships between genotype and phenotype
Genotype	Genetic constitution of an individual organism
Haplotype	A set of alleles found on the same chromosome that tend to be inherited together because of close proximity; alternatively, this definition can refer to one's genetic information at a set of polymorphisms on one chromosome that are not necessarily in strong linkage disequilibrium
Heritability	Proportion of observed differences on a trait among individuals of a population due to genetic differences; factors, including genetics, environment, and random chance, can all contribute to variation between individuals in their observable characteristics (in their phenotypes)
Insulator	A DNA element that, in order to regulate the enhancer influence of particular genes, blocks interaction between specific enhancers and promoters
Intronic sequence	Noncoding sequence removed from RNA through splicing
Linkage disequilibrium	A measure of the association (i.e., likelihood of coinheritance) of genetic variants (i.e., alleles) at different loci; when there is no association between genetic variants at different loci, they are in *linkage equilibrium*
Locus	Position of a gene or mutation on a chromosome
Methylome	All methylation modifications in the genome of a cell or population of cells (usually at a given point in time, under specific conditions)
MicroRNA	Small noncoding RNA molecule that functions in RNA silencing and posttranscriptional regulation of gene expression
Omics	Collective technologies used to explore roles, relationships, and actions of the various types of molecules that make up the cells of an organism; these technologies include genomics, ("the study of genes and their function" [Human Genome Project, 2003]), as well as transcriptomics and epigenomics, proteomics and metabolomics (entire sets of protein, metabolic factors), and others that are characterized under specific conditions.
Omics Reference genome	An assembly of nucleotide sequences used to represent the genome of a particular species; this sequence is used as a standardized platform to which genome data can be compared
Phenotype	Set of observable characteristics of an individual resulting from the interaction of its genotype with the environment
Phenotypic plasticity	Ability of one genotype to produce more than one phenotype when exposed to different environments
Polymorphism	A location (locus) in the genome that varies among members of a population; a polymorphism has two or more variants, and generally, the variant that is rarer must be present in ≥ 5% of the population or it is considered a mutation
Promoter	A region of DNA, upstream of the transcription start site, that initiates transcription of a particular gene
Proteome	The complete collection of proteins contained in a cell or a population of cells (usually at a given point in time, under specific conditions)
Quantitative trait loci	Genetic section of DNA that correlates with or is linked to variants associated with variation in a trait (a quantitative phenotype)
RNA-seq	Sequencing of all RNA transcripts in the cell, known as transcriptome profiling, determined using next-generation sequencing technologies
Selective sweep	Reduction or elimination of variation among the nucleotides in the neighboring DNA of a mutation as the result of recent and strong positive natural selection
Silencer	A region of DNA sequence to which proteins may bind and decrease gene expression
Single nucleotide polymorphism; (also known as single nucleotide variant)	DNA sequence variation occurring commonly within a population (e.g., 1%) in which a single nucleotide (A, T, C, or G) in the genome (or other shared sequence) differs between members of a biologic species or paired chromosomes
Systems biology	A biology-based interdisciplinary field of study that focuses on complex interactions within biologic systems, using a holistic approach (instead of traditional reductionism) to biologic and biomedical research
Transcriptome	Complete collection of RNA transcripts contained in a cell or a population of cells (usually at a given point in time, under specific conditions)
Twin studies	Methods used to assess genetic versus environmental contribution to traits; data from siblings and adoptees, from pedigree information, and from other aspects are commonly examined to determine the genetic role in development of a trait or behavior in twins
Whole-genome sequencing	A laboratory process that determines the complete DNA sequence of an organism's genome (also known as full-genome sequencing, complete-genome sequencing, and entire-genome sequencing)

BOX 117-2 Assessing the Quality of a Genome-Wide Association Study

1. Is the phenotype accurately and correctly defined?
2. Are potential confounding variables controlled between cases and controls?
3. Was the sample size appropriate?
4. Was the genotyping density appropriate?
5. Were the quality control steps sufficient?
6. Were previous associations replicated?
7. Were the statistical tests sufficiently stringent?
8. Was the result replicated in an independent population? Was the replication design sufficiently similar to the original study in terms of subject characteristics and phenotype?
9. Was the associated polymorphism demonstrated to have a functional role in the phenotype?

Attia J, Ioannidis JP, Thakkinstian A, et al: How to use an article about genetic association: C: what are the results and will they help me in caring for my patients? *JAMA* 301:304-308, 2009; Pearson TA, Manolio TA: How to interpret a genome-wide association study, *JAMA* 299:1335-1344, 2008.

roles (e.g., *microRNAs*, piRNAs, and structural and regulatory RNAs) have been extensively examined.[170,196]

The Encyclopedia of DNA Elements (ENCODE) Consortium suggests that most of the human genome contains DNA elements with biochemical relevance.[52] Extensive genome-wide expression analysis, initially completed in cell lines ranging from lymphoblastoid to primary liver cells, has provided candidate elements for future investigations of genome regulation. ENCODE analysis of RNA transcription helped identify epigenetic signatures of gene regulation (e.g., methyl marks on DNA [the *methylome*] and DNA hypersensitivity associated with decreased and increased transcription, respectively, and histone modifications associated with either repressive or activating transcriptional marks). Additional information regarding these regions is available at the ENCODE Data Coordination Center at the University of California Santa Cruz (UCSC) or on the UCSC Genome Browser (genome.ucsc.edu).

Many DNA variants associated with disease are identified within or near noncoding functional DNA elements. This provides important insight into the study of genetic variation and disease. Acute exposure to environmental wilderness conditions may initiate cellular, molecular, and, ultimately, physiologic compensations to such challenges. Understanding these responses will help advance our understanding of human disease, biology, and responses to environmental conditions.

TECHNOLOGIES FOR IDENTIFYING GENETIC VARIANTS AND THEIR ASSOCIATIONS WITH DISEASE

Various technologies may be employed to identify genetic variants and test for associations with disease. Genotyping or sequencing platforms allow for DNA and RNA sequence analyses, and various high-throughput methods may be used to detect epigenetic marks that influence gene expression and/or protein signatures and posttranslational modifications in cells or tissues. New genome-wide tools continue to improve accuracy and throughput, and investigators can select complementary approaches to address a wide range of research questions.

Microarrays based on hybridization techniques are used to assay large amounts of biologic material or simultaneously genotype multiple regions of the genome. Antibody arrays were among the first microarrays developed,[45] and "gene chips" followed in the 1990s.[208] Today, SNP hybridization microarrays can simultaneously genotype more than one million SNPs scattered throughout the genome. In these microarrays, chosen SNPs serve as reporters for a specific haplotype or DNA sequence. Precise DNA elements on the array are hybridized so that complementary sequencing of DNA or RNA can be performed under high-stringency conditions. This hybridization is detected and quantified by fluorophore-, silver-, or chemiluminescence-labeled targets. This technology is limited to specific markers, but has enabled progress (e.g., using GWASs and other genomic studies) by highlighting genetic patterns among individuals. In addition to DNA microarrays, various protein, peptide, and metabolism arrays are widely used for research.

In contrast to microarrays, *sequencing technologies* provide information across consecutive DNA or RNA sites in a targeted region or across the entire genome *(whole-genome sequencing)*. Next-generation sequencing technologies have revolutionized this effort through massively parallel sequencing.[220] The basic workflow requires library preparation (i.e., fragmenting and adding adapters to DNA that is then denatured and amplified). These fragments are sequenced and aligned with the *reference genome* (i.e., the nucleic acid sequence database that serves as the representative example of a species' genome).

Exome sequencing captures information from the protein-coding regions of the genome and has proved effective for identifying variants in rare Mendelian disease.[12] Knowledge of the protein-coding sequence has been applied to RNA sequencing for gene expression analysis (*RNA-seq* or whole-transcriptome sequencing). Additional efforts to categorize regulatory functions are achieved through *chromatin immunoprecipitation* (ChIP) followed by sequencing (ChIP-seq), and sequencing of methylated DNA (methyl-seq) (see Figure 117-9). In ChIP, interacting DNA-proteins (in chromatin) are cross-linked and sheared, and antibodies (targeted for specific proteins) precipitate a linked DNA-protein complex. The complex is then unlinked and the DNA purified for sequence analysis. ChIP is used to determine whether transcription factors and proteins (activating or repressive) are bound to a genomic region and so influence gene regulation and a phenotype of interest.

Sequencing technologies that are applied today have rapidly advanced since the 1980s (see Figure 117-6). Maxam-Gilbert (radiolabeled)[153] and Sanger (chain-termination)[205] sequencing preceded *de novo* sequencing of fragmented DNA. Shotgun sequencing, based upon fragmenting and then aligning genomic segments using overlapping regions, further improved output. Next-generation sequencing enabled parallel sequencing and simultaneous generation of millions of sequences. New methods (e.g., pyrosequencing, single molecule, Illumina/Solexa, SOLiD, Ion Torrent, nanoball, Heliscope, SMRT, nanopore, tunneling currents, and sequence by hybridization and mass spectrometry) are further advancing scientific techniques.[136]

Although such high-throughput technologies provide valuable insights, scientists need to determine the mechanism that enables gene variant(s) to *cause* a particular trait. These data can be obtained by testing mechanisms using genetically manipulated model organisms or cultured cells. For instance, demonstrating in a controlled experiment that a particular genetic variant decreases the rate of transcription of a gene or lowers the activity of the encoded enzyme provides good evidence that genetic association was causal.

GENETIC RESPONSES TO EXTREME ENVIRONMENTS

GENETICS AND ALTITUDE

Hypoxia and Acclimatization

High-altitude environments are physiologically stressful because of numerous abiotic factors (e.g., hypoxia, cold, heat, ultraviolet [UV] radiation, and wind). Although many stressors are easily mitigated (e.g., with warm clothing or sunscreen), the hypoxia of high-altitude environments cannot easily be avoided. Supplemental oxygen is expensive and difficult to carry; for these reasons, most humans at high altitude are constantly exposed to hypoxic stress.[256]

High-altitude hypoxia is due to hypobaria; ascent decreases barometric pressure and reduces partial pressure of oxygen.[256] High-altitude environments can be best simulated in chambers by decreasing the atmospheric pressure (i.e., hypobaric hypoxia) or the fraction of inspired oxygen (i.e., normobaric hypoxia). Although they are not equivalent, hypobaric hypoxia and normobaric hypoxia appear to elicit similar physiologic responses.[51,157,158,195]

Humans acclimatize to hypoxia through a series of physiologic responses (e.g., increased minute ventilation, bicarbonate diuresis, increased hemoglobin concentration).[14,17,206,219] Acclimatization to hypoxia increases oxygen availability and increases capacity for submaximal exercise.[69] Individual tolerance of acute and chronic hypoxia varies considerably.[145] Some individuals will develop acute altitude illnesses and others will remain healthy, despite traveling together and being exposed to the same hypoxic stress.[106] Similarly, only subsets of high-altitude natives and lifelong high-altitude residents develop chronic altitude illnesses.[199] Twin studies have demonstrated heritable control of ventilatory responses to hypoxia and hypercapnia and physiologic responses to hypoxic exercise (e.g., heart rate, oxygen saturation, and maximal oxygen uptake).[152] Additional evidence for individual responses to altitude comes from studies of altitude illness.

Altitude Illness

Altitude illness has acute and chronic presentations (Table 117-1). Acute altitude illness develops following a recent ascent to a new altitude (< 7 days, but most commonly at 1 to 4 days). The three major forms of acute altitude illness are acute mountain sickness (AMS), high-altitude cerebral edema (HACE), and high-altitude pulmonary edema (HAPE). Chronic altitude illnesses develop in humans following prolonged stays at high altitude (≥ 7 days, but more commonly several years). The most prominent chronic altitude illnesses are chronic mountain sickness (CMS) and high-altitude pulmonary hypertension (HAPH). Acute altitude illnesses are most likely to affect travelers to altitude; chronic altitude illnesses affect those who reside at altitude. Exceptions occur. Natives of high-altitude regions who travel to sea level can develop "reentry HAPE" on return to a high altitude,[104] and lowland residents can develop subacute mountain sickness (a condition similar to HAPH, characterized by right-heart failure) during a prolonged visit to high altitude[6] (Figure 117-10).

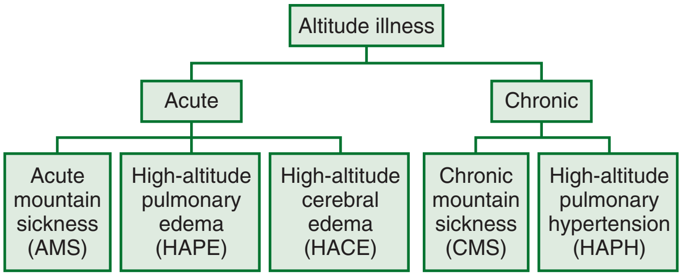


FIGURE 117-10 Altitude illnesses are either acute or chronic, depending on their typical time to onset.

TABLE 117-1 Advantages, Challenges, and Considerations for Studies of Altitude Illness

Altitude Illness	Advantages	Challenges and Considerations
Acute mountain sickness	Common Not fatal	Stability and repeatability Subjective diagnosis Ascent rate Altitude Timing of onset Susceptibility (age, gender) Comorbidities Many genes likely involved
High-altitude pulmonary edema	Objective diagnosis Stability and repeatability	Ascent rate Altitude Timing of onset Rare condition Rapidly fatal Susceptibility Comorbidities
High-altitude cerebral edema	Objective diagnosis Repeatability? Lasting signs of microhemorrhages	Stability and repeatability Ascent rate Altitude Timing of onset Rare condition Rapidly fatal Susceptibility Comorbidities
Chronic mountain sickness	Stable condition Objective diagnosis	Susceptibility (age, gender) Comorbidities Time at altitude Environmental factors
High-altitude pulmonary hypertension	Stable condition Objective diagnosis	Susceptibility (age, gender) Comorbidities Time at altitude

A brief review of high-altitude illnesses informs our discussion of genomics and personalized medicine. Please see Chapters 1 through 3 for a detailed review of altitude illness.

Acute Altitude Illnesses

Acute Mountain Sickness. Acute mountain sickness (AMS) is the most common form of altitude illness. It begins 6 to 10 hours after arrival at a higher altitude and resolves rapidly with descent.[70,85] Its prevalence depends on the altitude attained and the rate of ascent. AMS develops in normobaric and hypobaric hypoxia, but not in hypobaric normoxia,[195,197] suggesting that hypoxia (not hypobaria) is the primary precipitating factor for AMS.

The Lake Louise criteria define AMS as the presence of a headache (in the setting of a recent elevation change to > 2500 m), with at least one other symptom present (e.g., nausea, vomiting, dizziness, fatigue, or difficulty sleeping).[15] A Lake Louise score greater than or equal to 3 (with a headache) is diagnostic of AMS.

AMS symptoms are subjective and nonspecific and can mimic many other conditions (e.g., exhaustion, dehydration, alcohol hangover, and migraine).[18] Because symptoms are self-reported, the phenotype is subjective. Alternative questionnaires share similar flaws.[10,26,204,234,248,249] AMS likely results from hypoxia-induced cerebral perturbations,[106] and more research is needed to elucidate its physiologic basis.

Genetics of Acute Mountain Sickness. Differences in AMS susceptibility should encourage genetic study. The one twin study performed at altitude involved preverbal children, making generalizations to adults difficult.[267] A family history was not associated with AMS on an ascent to Mt Damavand, Iran (5671 m),[276] but AMS severity was correlated in brothers who ascended to Lake Gosainkunda, Nepal (4380 m).[143] Individuals of Tibetan ancestry seem less susceptible to AMS relative to other Asian populations (e.g., Han Chinese, Japanese).[133,263] Additional studies of twins, familial aggregation, family history, and biogeographic differences are needed.

Candidate-gene association studies have tested associations between AMS susceptibility and specific genetic variants.[147] None has identified a genetic variant with clinical utility. The angiotensin-converting enzyme (ACE) I/D polymorphism was originally associated with elite mountaineering performance; that is, relative to the general British population, elite climbers were more likely to carry the I allele, suggesting that these individuals had lower plasma ACE levels.[161] This is further supported by associations of the I/D polymorphism with arterial oxygen saturation in climbers ascending rapidly to 5000 m[259] and summit success on Mt Blanc, France.[241] Researchers hypothesized that this polymorphism could contribute to variation in AMS susceptibility (because susceptibility would hinder mountaineering). Several studies found that ACE polymorphisms were not associated with AMS at 3807 m, 4380 m, 4559 m, or 5895 m.[116]

Genetic studies of AMS susceptibility (see Table 117-1) have been hindered by AMS's unclear pathophysiology,[88,141] its variable presentation,[144,146] and the subjective criteria for diagnosis. Improved understanding of AMS pathophysiology or identification of objective biomarkers or signs of poor hypoxia acclimatization would benefit genetic studies of AMS. Genome-wide investigations might preclude need for *a priori* hypotheses, but more rigorous experimental designs and improved diagnoses will still be needed to strengthen genetic investigations into AMS susceptibility. If exposures (e.g., rate and final elevation of ascent) were standardized, results could more easily be compared across studies.

High-Altitude Cerebral Edema. High-altitude cerebral edema (HACE) is the rare, but potentially lethal, form of acute cerebral altitude illness defined by the presence of ataxia and/or altered mental status. It typically occurs at least 2 days after ascent to an altitude above 3000 m.[13] In the vast majority of cases, AMS precedes HACE.[85,86]

Magnetic resonance imaging studies of patients with HACE reveal vasogenic edema[87] and microhemorrhages in the corpus callosum,[60,115,210] indicating the blood-brain barrier has been disrupted. Without treatment or descent, HACE may within 24 hours progress to coma followed by death resulting from brain herniation.[13] Hemosiderin deposits (signs of brain microhemorrhages) remain in the brain of HACE survivors for decades.[210]

A HACE incidence of approximately 1% was reported in an early study.[84] A very large prospective study (> 14,000 high-altitude railway workers in China) reported a HACE incidence of 0.28%.[264]

Genetics of High-Altitude Cerebral Edema. The role of genetic variation in HACE susceptibility has not been investigated. No reports of individuals suffering repeated episodes of HACE or of familial aggregation of HACE have been published. Candidate-gene and genome-wide association studies have not been performed for HACE. Obtaining sufficient sample sizes to perform these studies would be advanced by the creation of a HACE database.

High-Altitude Pulmonary Edema. High-altitude pulmonary edema (HAPE) is the acute pulmonary manifestation of acute altitude illness and the leading cause of death due to acute illness. The onset of HAPE is generally 2 days after arrival at a new altitude (usually > 2500 m)[85,209] and is characterized by dyspnea at rest.[85,156,209] HAPE is a noncardiogenic form of pulmonary edema secondary to hypoxic pulmonary vasoconstriction as pulmonary arterial hypertension leads to stress failure of pulmonary capillaries and extravasation into alveolar spaces.[149,233] The HAPE incidence increases with ascent rate and altitude attained. Persons who are susceptible to HAPE demonstrate greater pulmonary artery pressure in response to normoxic exercise[82] and hypoxia (normobaric and hypobaric).[149] Persons susceptible to HAPE also have relatively lower level of exhaled nitric oxide.[41,63]

The risk of recurrence for HAPE is approximately 60% for persons who ascend to 4500 m in 2 days,[16] suggesting that a previous episode of HAPE is a strong risk factor for its redevelopment.

Genetics of High-Altitude Pulmonary Edema. HAPE is more amenable to research than is AMS or HACE. HAPE has demonstrable examination findings, which increases the certainty in diagnosis. HAPE is rare, but a subpopulation of susceptible individuals can be identified and studied prospectively with strong confidence in the quality of phenotypic data. HAPE field studies are still difficult because of its low incidence (and relatively longer time to onset) compared with AMS. Databases of individuals who have developed HAPE (as well as individuals who have traveled to high altitude but have not developed HAPE) are being created in an attempt to gather more information about the condition.[209]

HAPE family data include reports of HAPE susceptibility within siblings and within parent-offspring pairs.[68,105,140,212] Given that the incidence of HAPE is so low, reports of familial aggregation support a genetic cause (N.B., the potential effect of a shared environment cannot be ruled out). Biogeographic comparisons are not available for the incidence of HAPE.

Candidate genes investigated as markers of HAPE susceptibility are found in Table 117-2. A recent GWAS identified several candidate genes for HAPE susceptibility in Japanese individuals,[121] including a tissue inhibitor of metalloproteinase 3 (TIMP3), a gene whose product regulates the degradation of the extracellular matrix of lung tissue. Interaction of TIMP proteins and matrix metalloproteinases has been associated with various lung pathologies related to decreased structural integrity (e.g., edema, emphysema, fibrosis).[137] Based on the function of this gene and our current understanding of HAPE, this finding is intriguing. Intronic variants of the *EGLN1* gene have also been associated with HAPE in a population from India.[1] Research to confirm these results and to determine generalizability is needed.

Chronic Altitude Illnesses

Chronic Mountain Sickness. Chronic mountain sickness (CMS), or Monge's disease, is a condition that affects high-altitude natives and long-time residents of high altitude.[128] CMS generally develops after years of exposure to high altitude (i.e., ≥ 2500 m), gradually resolves with descent to lower altitudes, and can recur upon reascent to altitude.[128]

CMS is characterized by excessive erythrocytosis (females: hemoglobin ≥ 19 g/dL; males hemoglobin ≥ 21 g/dL). In addition, severe hypoxemia and pulmonary hypertension can occur.[128] Individuals with CMS can exhibit some symptoms similar to those of AMS (headache, dizziness, sleep disturbance, fatigue) in addition to dyspnea, tinnitus, alterations of memory, and bone or muscle pain.[126] Over time, pulmonary hypertension associated with CMS can cause right-heart failure (cor pulmonale) and congestive heart failure.[128]

Diagnosis of CMS requires exclusion of chronic pulmonary diseases or other chronic medical conditions that could cause severe hypoxemia.[128] A score is available to rate severity of CMS. Variables are rated on a scale of 0 to 3 and summed: breathlessness/palpitations, sleep disturbance, cyanosis, dilatation of veins, paresthesia, headache, tinnitus, and hemoglobin concentration.[128]

Only some highlanders develop CMS. Patients with CMS are hypoxic and may be hypercapnic due to relative hypoventilation.[127] In Andean patients with CMS, hypoxic ventilatory response is only modestly lower than that of healthy Andean highlanders,[127] suggesting that hypoxic ventilatory response is not the precipitating cause of CMS. Hypoventilation could result from erythrocytosis, because the hemodilution of patients with CMS increases ventilation[150,258]; however, whether or not erythrocytosis *causes* hypoventilation is unclear.[126] Limited increases in hemoglobin concentration counteract the effects of hypoxia by increasing oxygen-carrying capacity. Beyond a certain threshold, further increases in hemoglobin concentration increase blood viscosity and blood volume and become pathologic.[193,245] More research is needed to improve our understanding of the physiologic mechanisms leading to CMS.

The CMS prevalence varies widely between geographic locations and populations. There is a much higher prevalence of CMS in Andeans than in Tibetans despite both populations being native to regions of high altitude.[126,164] This difference is not due to location. The prevalence of CMS in Tibetan highlanders is approximately one quarter that of Han Chinese immigrants who inhabit the same region.[261] CMS has not been reported in Ethiopian highlanders.[126] The difference in incidence between Tibetans and Andeans could be the result of dissimilar physiology (e.g., higher alveolar ventilation and hypoxic ventilatory response and a lower hemoglobin concentration in Tibetans).[20,22,25,163]

Aging is associated with a greater prevalence of CMS: In one study, 27% of persons over 60 years, but only 7% of those between 20 and 29 years, had CMS.[129] Premenopausal females might be at lower risk for CMS.[125] A history of CMS, pulmonary dysfunction, hypopnea and sleep apnea, obesity, and exposure to environmental factors, such as air pollution and metals, could increase one's risk of developing CMS.[128]

TABLE 117-2 Candidate Genes Relevant to Wilderness Environment Phenotypes

Gene Symbol	Gene Name	Related Phenotype(s)	Protein Function*
ACE	Angiotensin I–converting enzyme	Responses to exercise training, exercise, performance, possibly AMS	Catalyzes conversion of angiotensin I to its physiologically active form, angiotensin II, which regulates blood pressure and fluid balance
ANP32D	Acidic (leucine-rich) nuclear phosphoprotein 32 family, member D	CMS	Tumor suppression
ARNT2	Aryl-hydrocarbon receptor nuclear translocator 2	Altitude adaptation	Under hypoxia, it forms a complex with HIF1alpha in the nucleus and binds to hypoxia response elements of oxygen-sensitive genes to increase transcription (i.e., a transcription factor)
BHLHE41	Basic helix-loop-helix family, member e41	Altitude adaptation	A transcription factor involved in the control of circadian rhythm and cell differentiation
CAMTA1	Calmodulin-binding transcription activator 1	Response to exercise training	Unclear
COL5A1	Collagen, type 5, alpha 1	Achilles tendinopathy	Alpha chain of a low-abundance fibrillar collagen
CREB1	cAMP-responsive element–binding protein 1	Response to exercise training	A transcription factor that binds to the cAMP-responsive element to induce expression
CYP19A1	Cytochrome P450, family 19, subfamily A, polypeptide 1	Physical activity	A monooxygenase that catalyzes the last steps of estrogen biosynthesis
CYP2C9	Cytochrome P450, family 2, subfamily C, polypeptide 9	Drug metabolism	Metabolizes many xenobiotics
CYP2C19	Cytochrome P450, family 2, subfamily C, polypeptide 19	Drug metabolism	Metabolizes many xenobiotics
CYP2D6	Cytochrome P450, family 2, subfamily D, polypeptide 6	Drug metabolism	Metabolizes as many as 25% of commonly prescribed drugs
CYP2E1	Cytochrome P450, family 2, subfamily E, polypeptide 1	Cold adaptation	A monooxygenase that catalyzes reactions involved in drug metabolism and the synthesis of cholesterol, steroids, and other lipids
CYP3A	Cytochrome P450, family 3, subfamily A	Salt homeostasis and hypertension	A monooxygenase that catalyzes reactions involved in drug metabolism and the synthesis of cholesterol, steroids, and other lipids
CYP3A4	Cytochrome P450, family 3, subfamily A, polypeptide 4	Drug metabolism	Metabolizes approximately 50% of commonly prescribed drugs
CYP3A5	Cytochrome P450, family 3, subfamily A, polypeptide 5	Drug metabolism	Metabolizes drugs as well as testosterone and progesterone
EDNRA	Endothelin receptor type A	Cold/hypoxia adaptation	Receptor for endothelin-1, a potent and long-lasting vasoconstrictor
EGLN1 (PHD2)	egl-9 family hypoxia-inducible factor 1	HAPE, altitude adaptation	Catalyzes hydroxylation of HIF1alpha protein to target the protein for degradation
EPAS1 (HIF2A)	Endothelial PAS domain protein 1	Altitude adaptation	A transcription factor that is regulated by oxygen tension
GUCY1A3	Guanylate cyclase 1, soluble, alpha 3	HAPH	Beta subunit of soluble guanylate cyclase, which catalyzes the conversion of GTP to 3′,5′-cyclic GMP and pyrophosphate
HBB	Hemoglobin, beta	Altitude adaptation (dogs)	A globin protein, which along with HBA, makes up the most common form of hemoglobin in adult humans, hemoglobin A
LEPR	Leptin receptor	Cold adaptation	A cytokine receptor for leptin that is involved in fat metabolism and lymphopoiesis
ME2	Malic enzyme 2, NAD(+)-dependent, mitochondrial	Cold adaptation	Catalyzes the oxidative decarboxylation of malate to pyruvate in the mitochondria [NAD(+)-dependent]
ME3	Malic enzyme 3, NADP(+)-dependent, mitochondrial	Cold adaptation	Catalyzes the oxidative decarboxylation of malate to pyruvate in the mitochondria [NADP(+)-dependent]
MICU1 (CBARA1)	Mitochondrial calcium uptake 1	Altitude adaptation	Regulates mitochondrial calcium uptake under basal conditions
NOS2	Nitric oxide synthase 2, inducible	Altitude adaptation	Synthesizes the signaling molecule nitric oxide
NOTCH1	Notch 1	Altitude adaptation	A transmembrane protein involved in developmental processes
PKLR	Pyruvate kinase, liver and red blood cell	Cold/hypoxia adaptation	Catalyzes the conversion of phosphoenolpyruvate to pyruvate and ATP (i.e., the rate-determining step of glycolysis)
PPARA	Peroxisome proliferator-activated receptor alpha	Altitude adaptation	A steroid hormone receptor that regulates lipid metabolism (i.e., a transcription factor)

Continued

TABLE 117-2 Candidate Genes Relevant to Wilderness Environment Phenotypes—cont'd

Gene Symbol	Gene Name	Related Phenotype(s)	Protein Function*
PPARG	Peroxisome proliferator-activated receptor gamma	Cold/hypoxia adaptation	A steroid hormone receptor that regulates adipocyte differentiation, as well as fatty acid storage and glucose metabolism (i.e., a transcription factor)
PRKAA1	Protein kinase, AMP-activated, alpha 1 catalytic subunit	Altitude adaptation	Catalytic subunit of AMP-activated protein kinase (AMPK), a cellular energy sensor that regulates key metabolic processes through phosphorylation
RGS18	Regulator of G-protein signaling 18	Response to exercise training	Attenuates the signal from G-proteins by increasing the activity of GTPase (increasing the conversion of GTP to GDP)
RYR2	Ryanodine receptor 2 (cardiac)	Response to exercise training	A receptor that when bound by calcium, releases calcium from the sarcoplasmic reticulum of cardiac muscle, triggering muscle contraction
SENP1	SUMO1/sentrin-specific peptidase 1	CMS	A cysteine peptidase that degrades members of the small ubiquitin-like modifier (SUMO) protein family
SGIP1	SH3-domain GRB2-like (endophilin) interacting protein 1	Physical activity	An endocytic protein that affects energy homeostasis
THRB	Thyroid hormone receptor, beta	Altitude adaptation	A nuclear hormone receptor for triiodothyronine (i.e., a transcription factor)
TIMP3	Metallopeptidase inhibitor 3	HAPE	Inhibits metalloproteinases, which degrade the extracellular matrix
TPMT	Thiopurine S-methyltransferase	Drug metabolism	Metabolizes thiopurine drugs
UCP3	Uncoupling protein 3	Cold adaptation	A skeletal muscle mitochondrial uncoupling protein that allows anions and protons to move between the inner and outer mitochondrial membranes (i.e., proton leak); ATP synthesis is separated from oxidative phosphorylation, with energy dissipated as heat
VAV3	Vav 3 guanine nucleotide exchange factor 1	Altitude adaptation	A guanine nucleotide exchange factor for Rho family GTPases; it is involved in angiogenesis
VKORC1	Vitamin K epoxide reductase complex, subunit 1	Drug metabolism	Reduces vitamin K 2,3-epoxide to its enzymatically activated form, which is essential for blood clotting

AMP, adenosine monophosphate; AMS, acute mountain sickness; ATP, adenosine triphosphate; cAMP, cyclic adenosine monophosphate; CMS, chronic mountain sickness; GDP, guanosine diphosphate; GMP, guanosine monophosphate; GTP, guanosine triphosphate; HAPE, high-altitude pulmonary edema; HAPH, high-altitude pulmonary hypertension; HIF, hypoxia-inducible factor; NAD, nicotinamide adenine dinucleotide; NADP, nicotinamide adenine dinucleotide phosphate.

Genetics of Chronic Mountain Sickness. Variation in CMS susceptibility across biogeographic groups is consistent with a genetic basis. A report of familial aggregation of CMS[192] led the way to recent candidate-gene and genomics investigations. Several candidate-gene association studies have been performed. Because they are limited by small sample size, they do not provide compelling evidence to link a specific gene or genetic variant to CMS susceptibility. A whole-genome sequencing study identified several genomic regions with haplotype patterns and frequencies consistent with the occurrence of selective sweeps.[274] These results are discussed in the next section on adaptation. In cultured fibroblasts, genes from a region containing *SENP1* and *ANP32D* had greater expression in the CMS-derived cells. Similarly, decreasing expression of these genes increased the survival of flies exposed to hypoxia. *SENP1* regulates erythropoiesis, so relative upregulation of this gene could have negative consequences for high-altitude dwellers (i.e., erythrocytosis).[49,270] *ANP32D* is an oncogene, but its putative role in the pathophysiology of CMS is unclear.

Cole and associates reported differences in the frequency of *SENP1* genotypes (rs7963934) between cases and controls in two independent cohorts.[50] In the same cohorts, the previously associated *ANP32D* SNP (rs72644851) was not associated with CMS. Because the two variants are in strong linkage disequilibrium, the authors suggested that the two original associations could represent one selection signal. Whether the same genes influence susceptibility to CMS in other populations is unknown.

High-Altitude Pulmonary Hypertension. High-altitude pulmonary hypertension (HAPH) (i.e., chronic mountain sickness of the vascular type, high-altitude heart disease, or subacute mountain sickness) is a chronic form of altitude illness characterized by excessive pulmonary artery pressure.[128] HAPH manifests following prolonged stays at altitudes above 2500 m. It can afflict high-altitude natives and lifelong residents of high altitude.[128]

HAPH is characterized by exaggerated pulmonary vasoconstriction, elevated pulmonary artery pressure (mean pulmonary artery pressures > 30 mm Hg and systolic pulmonary arterial pressures > 50 mm Hg), pulmonary vasculature remodeling, right ventricular hypertrophy, and congestive right-heart failure.[130] Excessive erythrocytosis may be present. HAPH can occur independent of CMS.[175]

In response to hypoxia, pulmonary vasculature constricts, elevating pulmonary artery pressure and pulmonary vascular resistance. With chronic hypoxia and increased pressure, pulmonary vessels remodel. In pulmonary arterial smooth muscle cells, calcium channels are upregulated and potassium channels are downregulated, leading to increased proliferation and vasoconstriction.[254] These vascular changes further increase vascular tone and increase thickness of the pulmonary vascular wall. The resulting elevated pulmonary vascular resistance augments right-heart afterload, which eventually leads to the right-heart failure associated with HAPH.[130]

HAPH prevalence increases in males and with increasing age.[131] In a group of Kyrgyz highlanders, 23% of males and 6% of females had electrocardiographic signs of cor pulmonale.[2]

Genetics of High-Altitude Pulmonary Hypertension. Familial aggregation for high-altitude heart disease (i.e., HAPH) was reported in three families living in the Qinghai region of China,[134] suggesting that HAPH susceptibility could be due to genetic variation or a shared environment. Tibetans generally have less pulmonary hypertension than do Andeans, which is consistent with genetic influence.[81]

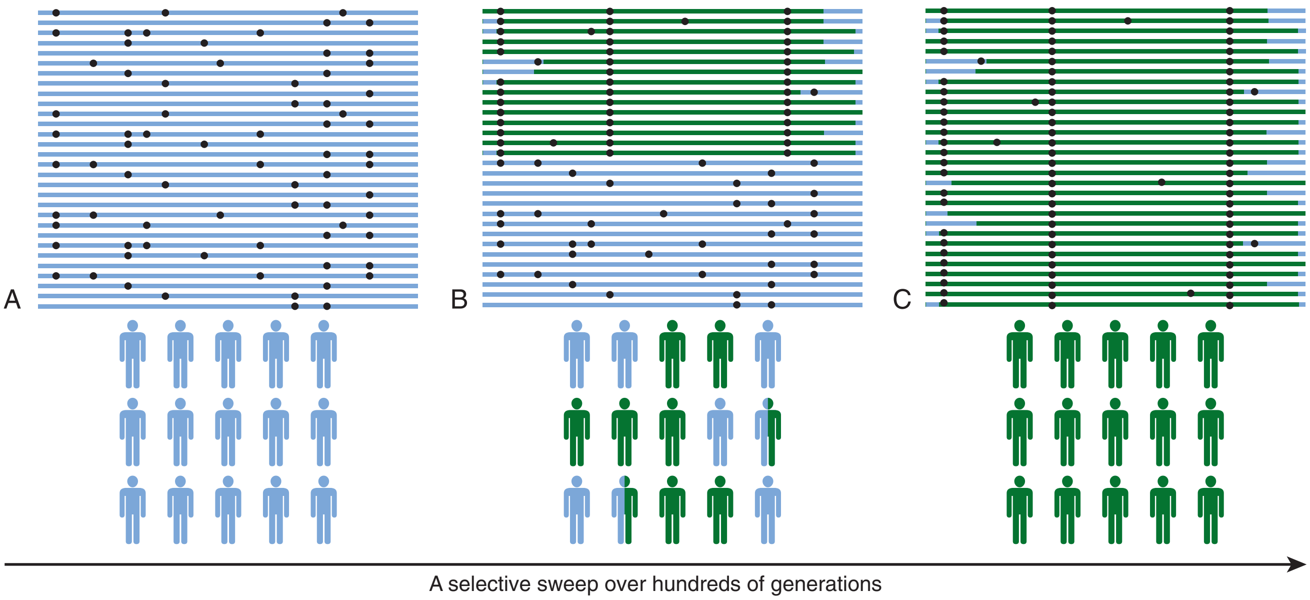


FIGURE 117-11 Progression of a selective sweep in genomes sampled from a population across many generations. **A,** Neutrally evolving chromosomal regions aligned for 15 individuals. Patterns in **B** and **C** represent chromosomal regions indicative of partial and complete selective sweeps, respectively. Statistics are used to identify patterns of haplotype homozygosity, exhibited as decreased variation around an adaptive variant, within a single population or between populations. *(Modified from Simonson TS: Altitude adaptation: a glimpse through various lenses,* High Alt Med Biol *16:125-137, 2015.)*

HAPH genetic analyses to date have focused on only a few candidate genes, and variants statistically associated with HAPH have not been replicated. A recent exome sequencing study of Kyrgyz highlanders with and without pulmonary hypertension identified GUCY1A3 (guanylate cyclase 1, soluble, alpha) as a candidate gene for HAPH susceptibility.[81] A rare missense mutation of the *GUCY1A3* gene was identified, and follow-up experiments revealed that the polymorphism under investigation altered activity of the soluble guanylyl cyclase (sGC) enzyme, which helps regulate pulmonary vascular homeostasis.[257] The authors hypothesized that the *GUCY1A3* variant protects against HAPH by enhancing sensitivity to nitric oxide. These findings highlight the importance of rare as well as common genetic variants involved in a phenotype.

High-Altitude Adaptation

Three continental populations have lived at high altitudes for hundreds of years. Ancestors of modern-day highlanders likely harbored beneficial variants in their genome sequences that have been selected over time.[23,27,29,224] Adaptive gene copies passed down over many generations create a pattern of variation distinct from neutrally inherited loci in the genome. The consequence of this process, called a *selective sweep,* may be detected by examining the variation of linked genetic markers *(haplotypes).* These analyses highlight important genetic signals in genomic data from as few as 30 individuals, a stark contrast to the thousands of subjects often required to identify possible genetic contributions in GWASs[178] (Figure 117-11). Regions that exhibit an adaptive signal are expected to contain functional variants favored by selection and are therefore valuable candidates for detecting genotype-phenotype associations. In contrast, populations whose genomes do not face strong selective pressure for a particular trait typically exhibit a random pattern of genomic variation and may have many variants that contribute small effects to neutrally evolving phenotypes.

Tibetan, Andean, and Ethiopian populations have inhabited high-altitude regions for hundreds of generations, a long enough time for natural selection to occur. Physiologic and genomic analyses in these groups suggest distinct evolutionary paths[19] (Figure 117-12).

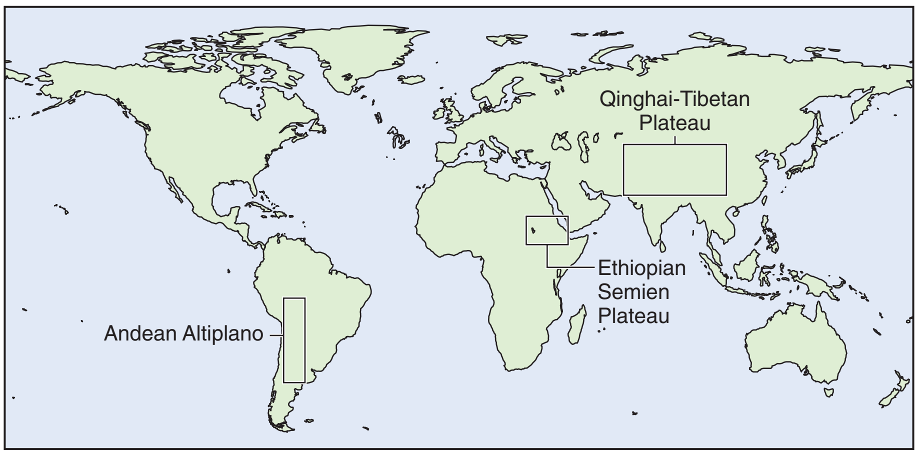


FIGURE 117-12 Map of high-altitude regions where data for evolutionary studies of adaptation have been collected. *(Modified from Simonson TS: Altitude adaptation: a glimpse through various lenses,* High Alt Med Biol *16:125-137, 2015.)*

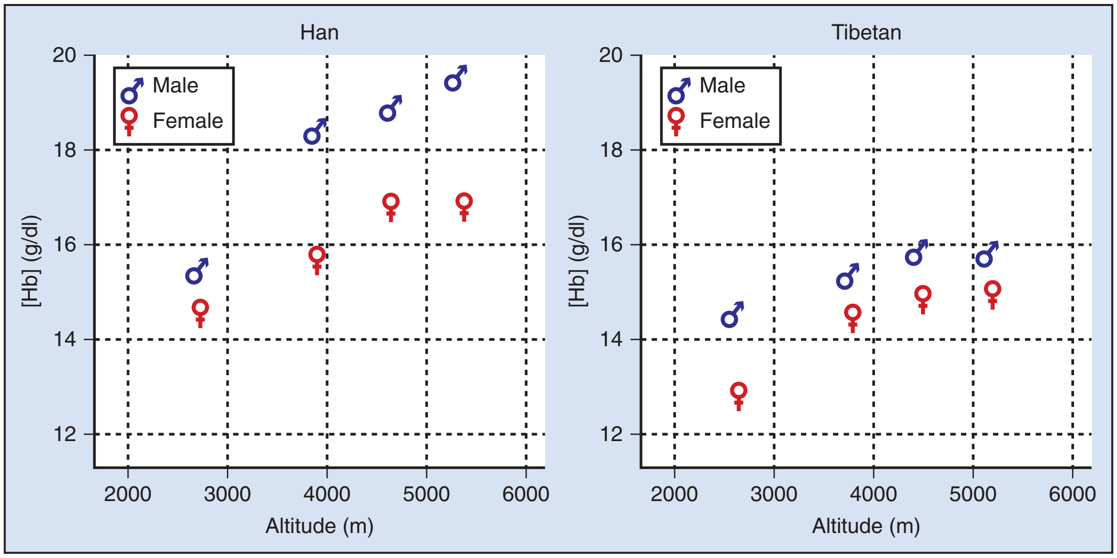


FIGURE 117-13 Hemoglobin concentration in Han Chinese and Tibetan males and females at various altitudes. *(From Gilbert-Kawai ET, Milledge JS, Grocott MPW, Martin DS: King of the mountains: Tibetan and Sherpa physiological adaptations for life at high altitude,* Physiology *29:388-402, 2014.)*

The largest high-altitude region continuously inhabited by human populations is the Qinghai-Tibetan Plateau. Some regions of the plateau have been inhabited for up to 25,000 years,[3,187,273] and genetic relationships between ancestors of present-day Tibetan and Sherpa groups date to approximately 30,000 years ago.[112] The adaptive *EPAS1* gene segment identified in Tibetans is most similar to the sequence in an archaic Denisovan, suggesting introgression into the Tibetan gene pool approximately 40,000 years ago.[103] Archeologic findings indicate that areas in the northeast region of the plateau were more recently occupied (5000 years ago).[47] Considering the plateau's vast area (nearly 100 million square miles), it is not surprising that various groups (e.g., Amdo, Kham, and Ü-Tsang Tibetans) exhibit distinct population structures and vary in terms of adaptive signals.[224,265]

Archaeologic findings indicate that humans established residence in the Andean highlands shortly after inhabiting South America approximately 12,000 to 14,000 years ago, with subsequent migrations to and from neighboring coastal environments.[189] European admixture in the 17th and 20th centuries contributed to the genetic pool of present-day Aymara and Quechua populations. In various Andean populations, genetic variants from populations that have historically lived in lowland areas underlie aspects of their physiology (e.g., the capacity for exercise at altitude).[64]

In Ethiopia, the demographic history of various groups (i.e., Amhara, Oromo, and Tigray) that inhabit intermediate to high altitudes (> 1800 m above sea level) is complex. There has been substantial gene flow from northern regions of Africa, the Middle East, and sub-Saharan Africa into the Ethiopian high-altitude population gene pool.[215] In addition to factors resulting from mixing among lowland and highland Ethiopian groups, non-African components make up 50% of the ancestry in Ethiopian populations.[171] Subpopulations located in the intermediate regions and highlands of Ethiopia exhibit a range of physiologic traits (e.g., variations in hemoglobin concentration) that likely reflect distinct population histories and lengths of residence at altitude.

Traits exhibited by native highland populations reflect distinct evolutionary paths.[19] More than 100 publications on physiologic adaptations in native highlanders can be found.[77] Some conclusions from these studies are inconsistent, likely reflecting varying methodologies, varying subpopulations, or limited sample sizes. The consensus suggests that specific components of oxygen transport play unique roles in different continental highland populations.[19,20,28,77,166,177]

Hemoglobin concentration is generally elevated in sojourners after a couple of weeks at high altitude. Hemoglobin levels in Tibetans increase much less than in lowlanders examined at high altitudes (e.g., Han Chinese)[262] (Figure 117-13). Individuals of Tibetan and Amhara highland Ethiopian ancestry living above 4000 m may exhibit hemoglobin levels comparable to those in lowlanders at sea level.[19,207] Andean high-altitude populations exhibit an average of a few grams per deciliter more hemoglobin than is exhibited by Tibetans.[22] Low hemoglobin levels in Tibetans and the Amhara are associated with adaptive genetic loci (discussed below). The physiologic significance is unknown. It is not clear if elevated hemoglobin is the primary or secondary consequence of adaptive changes in the oxygen transport system[223,228] (Figure 117-14).

An important variable in oxygen transport is ventilatory sensitivity to hypoxia. Hypoxic ventilatory response measures the increase in minute ventilation in response to the decreased arterial partial pressures of oxygen. Tibetan hypoxic ventilatory response values are similar to those of unacclimatized lowlanders, and Andeans exhibit a lower response comparable to that of acclimatized lowlanders.[20,25,54] Tibetans have greater lung, residual, and tidal volumes, greater total lung and vital capacities, and greater diffusing capacity than do Han Chinese lowlanders.[61,117,232] Hypoxic pulmonary vasoconstriction directs pulmonary blood flow to better-oxygenated portions of the lung. Hypoxic pulmonary vasoconstriction is increased in many lowlanders at altitude,[174] resulting in pulmonary hypertension. Tibetans have muted hypoxic pulmonary vasoconstriction during rest or exercise at altitude[81] or after examination following extended residence at sea level.[176] Histologic study of Andean pulmonary artery structure gives evidence of pulmonary hypertension.[7,94,95,242] In Ethiopians, the pulmonary vascular response to hypoxia includes elevated pulmonary pressure but not increased vascular resistance. In this population, increased pulmonary pressure may be attributed to increased blood flow.[99]

One study in Tibetans indicates that mothers with a high–arterial saturation of oxygen genotype have decreased offspring death rates compared with those with a low–arterial saturation of oxygen genotype.[24] Comparisons of Tibetan and Sherpa groups with other highland and lowland populations have revealed greater,[40,48] lower,[21] or equivalent[120] oxygen saturations. Comprehensive analysis suggests equivalent saturations.[255] The hemoglobin-oxygen binding affinity in highland populations varies among studies.[11,165,167,203,223,235] The resting, in vivo, binding affinity of blood with oxygen appears higher in Andeans and highest in Tibetan groups.[11,223]

Compared with lowland Han Chinese at high altitude, Tibetan and Sherpa populations exhibit elevated heart rates,[185,186,232,260] greater stroke volume and cardiac output,[48,73,260] and less right

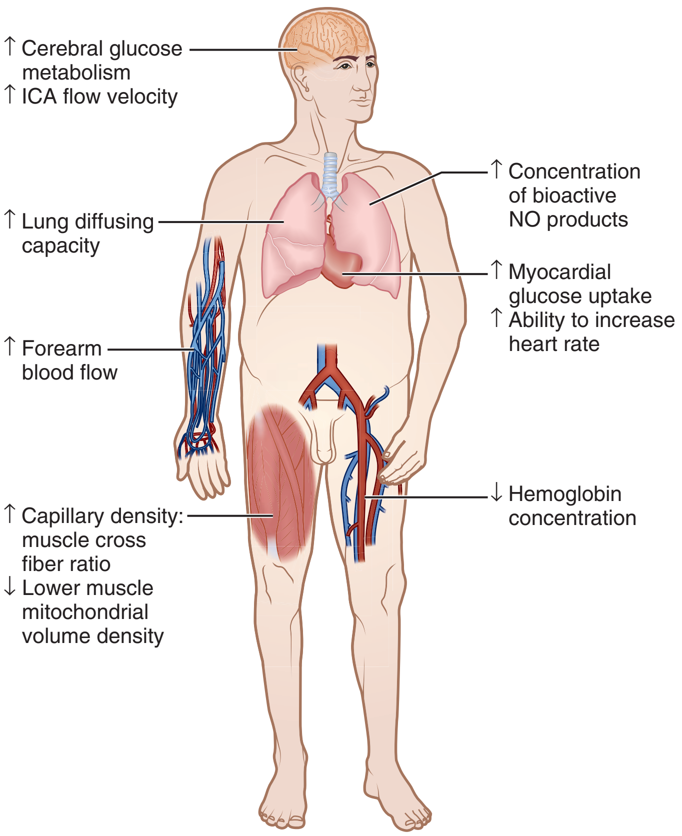


FIGURE 117-14 Summary of physiologic differences described in Tibetan and Sherpa individuals, as compared with lowlanders. *(From Gilbert-Kawai ET, Milledge JS, Grocott MPW, Martin DS: King of the mountains: Tibetan and Sherpa physiological adaptations for life at high altitude,* Physiology *29:388-402, 2014.)*

heart hypertrophy.[89] Compared with lowlanders at altitude, Sherpa exhibit smaller left ventricular size.[227] Cardiac metabolism studies in Tibetans and Sherpas suggest a shift toward glucose metabolism (decreasing oxygen demand), possibly due to decreased energy reserve.[100] In Sherpas examined at low altitude, the myocardial phosphocreatine–to–adenosine triphosphate ratio is half that of lowlanders, but is not further depressed following administration of a hypoxic gas mixture. This suggests a metabolic optimization for cardiac hypoxic conditions.[98] In lowlanders acutely exposed to hypoxia, downregulation of beta-adrenergic receptors decreases sympathetic nervous system stimulation. In Tibetans, greater vagal dominance at high and low altitude has been reported.[275]

In the brain, improved autoregulation and increased oxygen delivery have been hypothesized to be beneficial at altitude. At extreme altitudes, Sherpas compared with lowlanders demonstrate decreased psychoneurologic symptoms and less mild cortical atrophy and/or periventricular high-intensity signal areas in the white matter.[71] Tibetans and Sherpas have a greater internal carotid artery blood flow velocity,[101] which may increase oxygen delivery. At high altitude, positron emission tomography scans of glucose metabolism in Sherpas and lowlanders are comparable, suggesting that reduced cerebral metabolism does not occur in Sherpas. A reduction is observed in Andean populations.[98]

Compared with lowland groups, native Tibetan and Andean highlanders exhibit greater birth weights.[164] The mean decline in lowlander birth weight is typically 100 g per 1000 m of altitude.[166] Increased uteroplacental oxygen delivery is attributed to increased common iliac blood flow into uterine arteries, with greater placental volumes and less uterine growth retardation. Compared with all other groups, Tibetans generally have lower rates of prenatal and postnatal death, premature birth, hypertension, and preeclampsia.[164,240,271]

Are physiologic differences in populations exposed to high altitude due to distinct evolutionary trajectories or to different temporal snapshots of a shared, consistent evolutionary process? Given that multiple adaptive traits and genetic factors have been described, it is likely that each evolutionary course is distinct.

No reports have specifically examined unfavorable outcomes in populations well adapted to altitude that descend to low altitude. Tibetan males born and raised at altitude that moved to sea level exhibited an average hemoglobin concentration significantly lower than that of sea-level Han Chinese at the same altitude (14.2 g/dL ± 0.9 g/dL vs 15.3 g/dL ± 1.2 g/dL, respectively).[176] This sea-level Tibetan cohort exhibits blunted pulmonary vascular responses to acute and sustained hypoxia, and at the cellular level demonstrates lower expression of certain genes regulated by hypoxia-inducible factor (HIF). These changes could have implications for oxygen signaling and processing, including the potential for metabolic inflexibility.[72]

Genetics of Altitude Adaptation. Permanent residents at altitudes more than 2500 m above sea level who exhibit adaptations to hypoxia have been most extensively studied in terms of altitude genomics. These groups provide a "natural experiment" in which genetic approaches can be used to uncover the causes of adaptive variation,[19] increase our understanding of the adaptive process, and help elucidate the causes of disease.

Efforts to identify adaptive genetic factors have included a candidate-gene approach, where single genes are sequenced and tested for associations with a trait of interest. This proved successful in identifying hemoglobin variants underling oxygen-binding affinity in high-altitude deer mice[230,231] and hummingbirds.[184]

Genome-wide signatures of selection have been identified using high-throughput genotyping technologies. These genomic regions are typically highlighted by dramatic differences in allele frequencies at particular loci or long continuous stretches of linkage disequilibrium, as a pattern of extended linkage disequilibrium is characteristic of a selective sweep (see Figure 117-11).

HIF is likely involved in altitude adaptation (Figure 117-15). HIF transcription factors are heterodimers, composed of a constitutively expressed HIF-1 beta (β) subunit and three labile alpha subunits (HIF-1α, HIF-2α, HIF-3α), that, under normal oxygen tensions, are targeted for degradation. In low-oxygen conditions (hypoxia), HIFs escape degradation and bind to a core DNA sequence within hypoxia response elements. HIFs recruit coactivators and increase transcription of hypoxia-responsive genes.

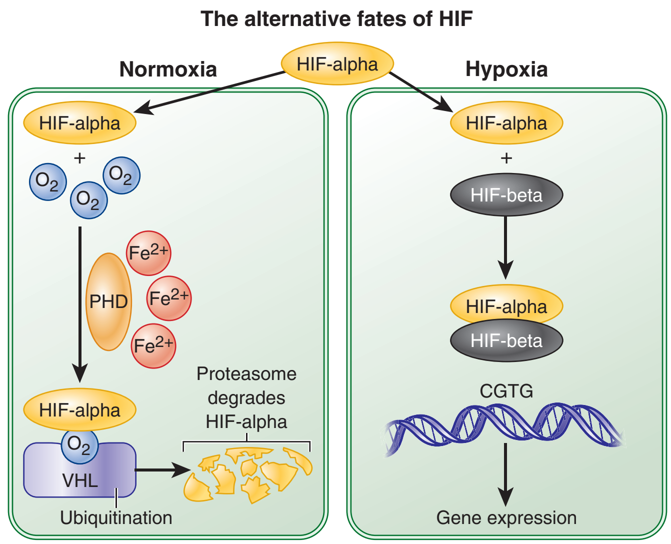


FIGURE 117-15 General diagram of the hypoxia-inducible factor (HIF) pathway. PHD, Prolyl hydroxylase; VHL, von Hippel-Lindau. *(From Petousi N, Robbins PA: Human adaptation to the hypoxia of high altitude: the Tibetan paradigm from the pregenomic to the postgenomic era.* J Appl Physiology *116:875-884, 2014.)*

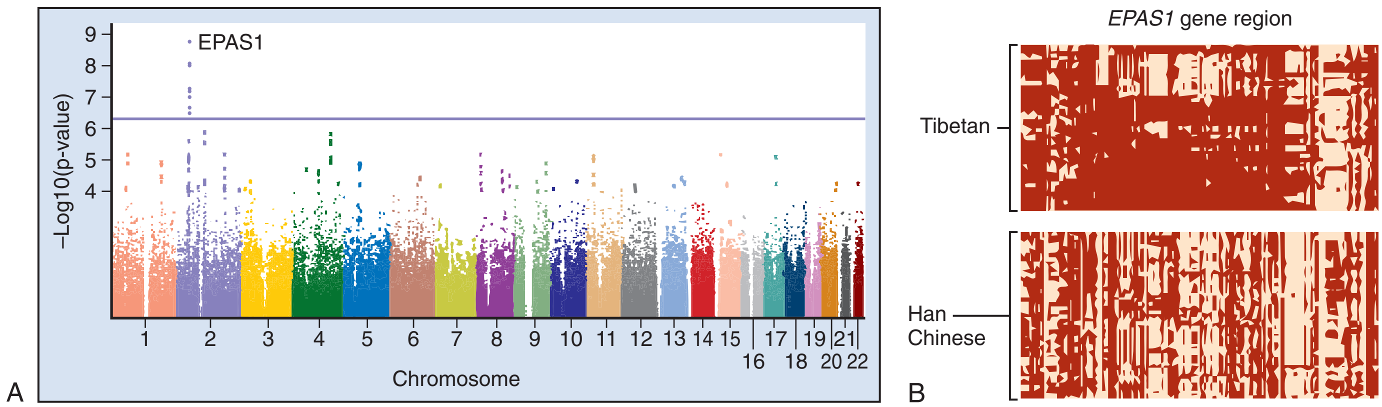


FIGURE 117-16 **A,** Results of a genome-wide allelic differentiation scan in Tibetans (chromosomes shown on the *x*-axis; significance, shown as –log10 of p value, on the *y*-axis). SNPs in the *EPAS1* gene region exhibit the most significant signal. **B**, Haplotype patterns in Tibetan (*top*) and Han Chinese (*bottom*) chromosomes in the genomic segment containing the *EPAS1* gene. (**A** *from Beall CM, Cavalleri GL, Deng L, et al: Natural selection on EPAS1 (HIF2 alpha) associated with low hemoglobin concentration in Tibetan highlanders*, Proc Natl Acad Sci USA *107:11459-11464, 2010;* **B** *from Simonson TS, Yang Y, Huff CD, et al: Genetic evidence for high-altitude adaptation in Tibet*, Science *329:72-75, 2010.)*

This facilitates acclimatization and adaptation to hypoxia by improving oxygen delivery and stimulating anaerobic glycolysis to compensate for insufficient oxidative phosphorylation. There are hundreds of known HIF target genes with established roles in developmental and physiologic processes (e.g., metabolism, proliferation and survival, iron and erythropoiesis, and vascular biology). These genes have been implicated in various disease states, including myocardial ischemia, stroke, different types of cancer, and pulmonary hypertension.[191,214]

Some of the strongest human adaptive signals have been identified in the genomes of native highland populations. A genome-wide scan of Andeans using a high-density SNP genotyping platform showed that thousands of SNPs were differentiated between Andean Quechuas residing at high altitude and nearby lowland populations.[29] This analysis focused on SNPs near HIF pathway genes. Thirty-six genes appeared to be under selection.

A study of Tibetans examined genome-wide patterns of SNPs and identified candidate genes within regions of the genome exhibiting a selective sweep.[224] Several of these genes intersected with an *a priori* list of functional candidates (e.g., *EGLN1*, *EPAS1*, and *PPARA*) in the HIF pathway. An analysis based on sequences from only protein-coding regions of the genome (i.e., the exome) identified 30 candidate genes in Tibetans of which *EPAS1* and *EGLN1* showed the strongest signals.[268] Another study confirmed that *EPAS1* is under positive selection in an independent cohort of Tibetans[23] (Figure 117-16) and that *EGLN1* is under selection in both Tibetans and Andeans.[27]

Neither *EPAS1* nor *EGLN1* have been found to be under positive selection in Ethiopian highlanders (Amhara and Oromo).[4] *PPARA,* reported as a selection candidate in one Tibetan study,[224] exhibits a signal of selection in an Amhara Ethiopian population and is associated with lower hemoglobin concentration.[207] This study identified other genes involved in the hypoxia response pathway (e.g., *CBARA1* and *VAV3,* and *THRB* and *ARNT2*). A third study of Ethiopian populations (i.e., Amhara, Oromo, and Tigray) highlighted different adaptive genes involved in the HIF pathway (e.g., *BHLHE41*).[102]

Certain adaptive targets in humans have been reported as targets of selection in other species.[222] Variants at the alpha and beta hemoglobin loci underlie greater hemoglobin-oxygen binding affinity in high-altitude deer mice[168,229,230] and hummingbirds in South America.[184] Adaptive signals at *EPAS1* and *HBB* have been identified in domesticated dogs at altitude.[66,79,251] Yak share an adaptive selection signal with Tibetans at the *ADAM17* locus.[188] In *Drosophila,* genes in the Notch pathway are top candidates of adaptation, and decreased expression of two neighboring candidate genes, *SENP1* and *ANP32D,* originally identified through comparative analysis of Andeans with and without CMS, exhibit increased survival when exposed to hypoxia.[274] Gene expression at these two genes was also increased in fibroblasts derived from individuals with CMS compared with those without CMS[274] (Figure 117-17).

Some adaptive candidate genes appear unique to particular subpopulations within a geographic region. This may be due to (1) false-positive signals, possibly as a result of demographic history, (2) substructure among major groups, and/or (3) different analytic methods employed by various investigators,[265] including the selection of comparative populations.[102] Efforts to account for such differences in future studies and standardize methods will help elucidate adaptive genetic signals shared between groups, and help establish genetic causes for physiologic differences between native highland populations.

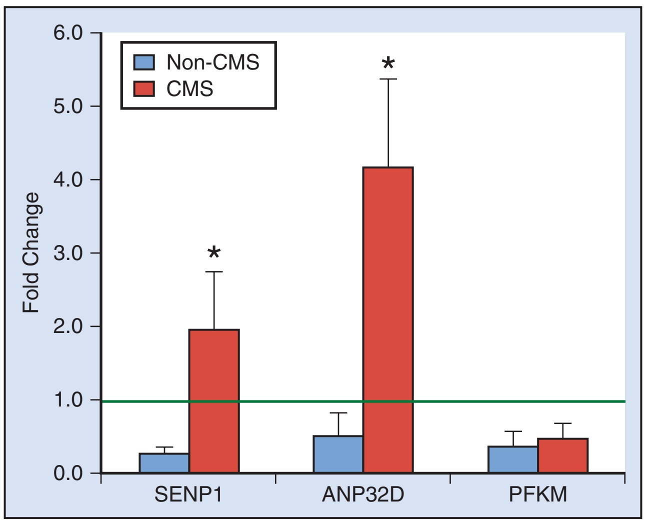


FIGURE 117-17 *SENP1* and *ANP32D* are both upregulated under hypoxia conditions in fibroblasts derived from subjects with chronic mountain sickness (*CMS*) compared with persons without the disorder (*green line* represents normoxia controls). *(From Zhou D, Udpa N, Ronen R, et al: Whole-genome sequencing uncovers the genetic basis of chronic mountain sickness in Andean highlanders,* Am J Hum Genet *93:452-462, 2013.)*

GENETIC INFLUENCES ON ADAPTATION TO TEMPERATURE AND ULTRAVIOLET RADIATION

As human populations migrated throughout the past 100,000 years, they encountered diverse environments. These variables (e.g., altitude, as described in the previous sections, temperatures, ultraviolet (UV) light exposure, and food sources) may have contributed to phenotypes observed among human populations. Given that some traits are observed as gradients, both genetic contributions and phenotypic plasticity (as a result of genetic or epigenetic underpinnings) likely underlie these differences.

Major environmental components vary across geographic ranges (e.g., temperature and humidity). Body mass and frame are noted as distinct among geographically diverse human populations. People of northern compared with equatorial latitudes have shorter distal-to-proximal limb ratios.[118,198] It is hypothesized that elongated bodies more effectively dissipate heat than do more spherical forms. Similarly, Arctic populations exhibit increased basal metabolic rate compared with non-Arctic populations.[132]

Differences in UV exposure and melanin production correlate with geographic location. In northern latitudes, where damaging effects of UV exposure are relatively limited, lighter skin pigmentation is adaptive. Less melanin encourages sufficient UV penetration of the skin to allow for vitamin D production needed for calcium regulation and bone growth.[46,110]

Associations between SNPs and metabolic genes have been identified in polar ecoregion populations.[90] Genes involved in oxidative metabolism *(ME2* and *ME3),* respiratory rate and body mass index *(LEPR),* cold resistance *(UCP3),* lipid oxidation, and brown adipose or nonshivering thermogenesis also harbor SNPs with extreme allele frequency differences or haplotype structures indicative of selection, suggesting a genetic underpinning to cold adaptation.[90,92] Evidence for climate adaptation (across nine climate variables) is provided in the Hancock and colleagues article of 2011.[91] SNPs associated with skin color, immunity and UV radiation, immunity and infection, and cancer pathways were also identified.[91]

Additional metabolic candidates of adaptation have been reported. Analyses of candidate genes from 52 worldwide populations suggest that variants in *CYP3A* are related to salt homeostasis and hypertension.[238,269] Various metabolic pathway genes appear as top candidates in Tibetan highlanders and neighboring or recent migrant Mongolian populations (e.g., *EPAS1, PKLR, CYP2E1, EDNRA, PPARG*). It is unclear if these signals reflect specific or integrated responses to environmental conditions (e.g., cold temperature in addition to hypoxia).[266]

GENETIC INFLUENCES ON EXERTION IN THE WILDERNESS

Many wilderness pursuits require increased levels of exertion for which a person may engage in a training regimen. Understanding individual variations in cardiovascular fitness and responses to exercise training is relevant to outdoor enthusiasts. Similarly, preventing exercise-related injuries and illnesses is especially important in remote and austere settings. Exercise genomics studies focus on explaining variations in cardiovascular fitness or exercise performance.[93]

PHYSIOLOGY OF EXERCISE

Exercise requires integration of many systems (e.g., cardiovascular, muscular, and respiratory systems). During exercise, muscle contractions require energy in the form of adenosine triphosphate (ATP), and production of ATP in the mitochondria requires oxygen. As exercise intensity increases, demand for ATP and for oxygen increases.

Total oxygen delivery, the amount of oxygen transported by the cardiovascular system each minute, is the product of the cardiac output (heart rate × stroke volume) and the arterial oxygen content. Cardiac output increases with exercise intensity. Arterial oxygen content remains relatively constant during exercise. To oxygenate blood and remove carbon dioxide, ventilation increases with exercise intensity. The peripheral vasculature contracts, redirecting blood to where it is most needed (i.e., exercising muscles) and away from where it is not needed (i.e., splanchnic region). With training, cardiac output is increased and greater ventilation rates can be achieved, increasing work rates.

The maximum volume of oxygen that can be taken up and used by the body is known as VO_2max. The theoretical upper limit for oxygen use is determined by cardiac output and oxygen extraction (i.e., the fraction of oxygen that can be extracted from blood). The VO_2max is determined by having subjects perform incremental exercise tests until they become exhausted. Cardiac output is a major factor in determining VO_2max, and is influenced by training status.[202] Changes in oxygen extraction occur with training, but these changes explain less of the change in VO_2max than do central adaptations.[201]

Physiologic factors influencing exercise performance include body morphology, endurance, strength, and power.[83] Each sport requires a different combination of these parameters. In addition, psychologic factors, training, and nutrition influence exercise performance.

EXERCISE GENOMICS

Exercise genomics studies first must determine the phenotype of interest. Studies may take a reductionist approach and measure a phenotype at the biochemical level or an applied approach and measure performance for a particular sport. Training heavily influences a person's physiology and performance. An elite athlete will have spent years training and practicing for a specific sport; this is likely the reason why training responsiveness is favored over exercise performance in genomics studies.[32,190] These factors must be considered when designing studies. For most exercise-related phenotypes, there is abundant variation among individuals. Twin and family studies indicate that genes may be associated with these phenotypes.

Human Variation and Studies Relating Genes to Performance

There is tremendous interindividual variation for exercise-related traits. Elite male endurance athletes (e.g., runners, cyclists, cross-country skiers) can have VO_2max values of 75 mL/kg/min or more and cardiac outputs of approximately 30 to 40 L/min.[56,65] VO_2max and cardiac output of elite female endurance athletes are lower but still high (e.g., ≥ 65 mL/kg/min and ≈ 25 L/min).[56,250] In young, trained men and women, VO_2max and cardiac output values are approximately 60 and 50 mL/kg/min and 25 and 20 L/min, respectively.[169] In comparison, untrained, recreationally active males might have VO_2max and cardiac output of approximately 45 mL/kg/min and 20 L/min, whereas females in this category have values of approximately 35 mL/kg/min and 15 L/min.[169] Improvements in VO_2max and individual traits in response to training are also highly variable.[9,34,247]

Other parameters related to exercise performance also vary (e.g., the proportion of type I muscle fibers in the vastus lateralis, height, and body mass index).[43] Given that the main factors underlying exercise performance (e.g., endurance, muscular strength, body composition, and height) are heritable and influenced by the environment (e.g., training and nutrition), it is not surprising that human exercise performance varies widely. The difficulty is in separating which of these phenotypic variations is attributable to genetic differences and which to environmental differences. We will discuss studies employing genomics-level techniques or studies that have been robustly replicated. The reader is directed to previous reviews for a more in-depth review of exercise genomics.[139]

Baseline Fitness

Family and Twin Studies. Family and twin studies have investigated the extent to which genetic differences explain variations in individual fitness levels. VO_2max is a heritable trait.[32] Heritability of baseline VO_2max was estimated to be approximately 50% in sedentary individuals.[34] Other exercise-related traits that are significantly heritable are the submaximal exercise work capacity and VO_2, ventilatory threshold, heart dimensions and mass, cardiovascular responses to exercise, muscular strength and endurance, flexibility and strength, fatigue resistance, neuromuscular performance, and body composition.[173,226] In addition to these physiologic parameters, the tendency of a person to participate in sports and leisure time physical activity has been reported to be heritable.[57]

Genetics of Exercise Capacity. Few genomics studies have attempted to determine which genes are associated with a baseline variation in exercise capacity. Several genome-wide linkage analyses have identified chromosomal regions associated with fatigue resistance,[237] exercise participation,[58] and physical activity levels.[42,221] These studies support a genetic basis for physical activity (and inactivity) but only identify regions of interest that harbor many genes. A GWAS to identify the specific genetic variants associated with variation in leisure time physical activity identified five such genes.[58] Two of these genes (*CYP19A1* in a Dutch sample; *LEPR* in an American sample) were replicated. A third gene *(SGIP1)* was not replicated but had a plausible physiologic role in exercise behavior. *SGIP1* and *LEPR* are expressed in the hypothalamus and are thought to regulate energy homeostasis. These studies suggest that genetic differences influence levels of physical activity in humans, even if individual genes have only modest effects.[119]

TRAINING RESPONSIVENESS

Due to differences in human activity levels and nutrition (i.e., environmental factors), it is difficult to investigate the role genetics plays in baseline fitness. More insight is likely gained by comparing individual responses with standardized exercise programs. These studies often use a within-subject design: subjects train for a set period of time and comparisons are made between pretraining and posttraining measurements. Genetic studies attempt to identify interactions between the genotype and training response.

Family and Twin Studies

The influence of heritability on responses to training has been studied. Increases in VO_2max following a standardized aerobic training protocol had a heritability of approximately 50% (coincidentally similar to the heritability for the baseline VO_2max).[33] Other responses to aerobic training found to be significantly heritable include cardiovascular responses to exercise, flexibility and strength, skeletal muscle enzyme activities, blood lipid concentrations, and glucose homeostasis.[37]

Genetics of Training Responsiveness

An early genomics study of training responsiveness used gene expression data in combination with genotype data.[239] The authors inferred that differential gene expression reflected underlying genetic variation in those genes. As such, associations between gene expression and the training response would indicate associations between the change in VO_2max and SNPs in those genes. The authors identified 11 SNPs that accounted for 23% of the variation in VO_2max trainability in the HERITAGE cohort. An independent GWAS performed on this same cohort identified a set of 21 SNPs, explaining 49% of the variation in VO_2max trainability (e.g., *CAMTA1*, *RGS18*, *RYR2*), or essentially all of the genetic variation in this trait[33] (Figure 117-18). None of the SNPs overlapped between the two studies, though 4 of 11 SNPs identified were close to significance (i.e., $p < 0.008$) in the GWAS. The study by Bouchard and associates[36] was recently supplemented with an integrative pathway analysis to discover specific pathways related to VO_2max trainability (e.g., protein kinase signaling, calcium signaling, immune responses, lipid metabolism, and cellular energetics).[75]

Nine SNPs associated with submaximal heart rate response to exercise training have been identified.[5] These SNPs explained the full heritability of the heart rate response to training (≈ 34%).[5]

These studies have limitations. In the HERITAGE family study, only sedentary individuals were tested, and the training protocol consisted of moderate-intensity continuous training and lasted 20 weeks. It is unclear whether the same genes would explain variation in training responses if subjects had a higher level of baseline fitness, performed other modes of training (i.e., high-intensity interval training), or trained for different durations.[32]

ATHLETIC PERFORMANCE

Another approach to identify genes involved in fitness is to compare athletes and nonathletes. Subjects are selected based on their success in organized sports. Given the paucity of successful international athletes, it can be difficult to obtain large sample sizes. Selecting appropriate controls is also difficult because athletic status is likely influenced by many environmental factors.

Family and Twin Studies

Athletic status was 66% heritable in a group of British female twins, suggesting that genetic variation could explain some of the differential success in organized sports.[59] Given that numerous exercise-related traits and responses to exercise training are

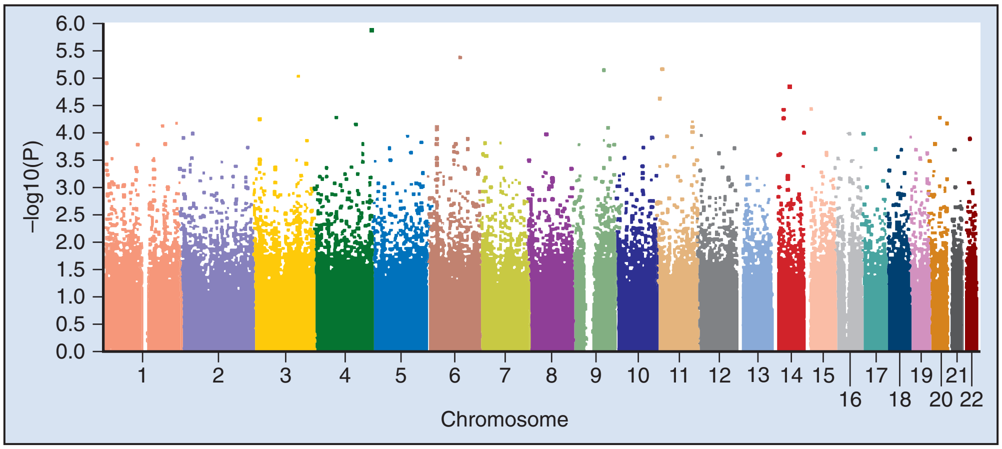


FIGURE 117-18 Results of a genome-wide association study (GWAS) for VO_2 response to exercise training in Caucasian individuals (chromosomes shown on the *x*-axis; significance, shown as –log10 of p value, on the *y*-axis). *(From Bouchard C, Sarzynski MA, Rice TK, et al: Genomic predictors of the maximal O_2 uptake response to standardized exercise training programs,* J Appl Physiol *110:1160-1170, 2011.)*

heritable, it is reasonable to hypothesize that overall athletic ability is also a heritable trait.

Genetics of Athletic Performance

There are no published GWASs for athletic performance. In a recent review, Pitsiladis[181] references three abstracts presented in 2012 related to genomics in sprinting performance, suggesting that genomics data for elite athletic performance might be available soon. The same review also points out a number of existing cohorts that would be amenable to GWASs. Although genome-wide techniques have not been applied to this area of exercise science, a plethora of candidate-gene association studies have investigated the influence of specific genes on athletic success. The *ACE* gene will be discussed briefly as an example.

The *ACE* gene was the first one to be associated with human performance.[161] As previously noted, the II genotype is overrepresented in elite mountaineers relative to the general British population. In an independent sample of the same study, subjects with the II genotype demonstrated a greater training response to resistance exercise than did subjects with ID or DD genotypes. In most follow-up studies, the II genotype is associated with endurance performance,[83] except in elite Ethiopian[8] or Kenyan[213] runners. It is likely that one or more variant(s) in the *ACE* gene contribute to endurance performance but are not absolute indicators of potential athletic success. *ACTN3* is another gene often studied.[83]

SUSCEPTIBILITY TO INJURIES AND ILLNESSES RELATED TO EXERCISE

Understanding the variation in susceptibility to sports-related injuries and illnesses (e.g., concussions, exercise-induced asthma, and ligament injuries) is relevant to athletes, coaches, and physicians. Future genomics studies may inform clinical medical practice.

Achilles tendinopathy has been the subject of numerous candidate-gene association studies. Tendons are fibrous connective tissues composed largely of various collagen types and connect muscle to bone. Tendon injuries are among the most common (30% to 50%) sports injuries.[111] Both the soleus and gastrocnemius attach to the calcaneus via the Achilles tendon. Because these muscles are the major plantarflexors, large forces are placed on the Achilles tendon during weight-bearing exercise. Of sports injuries, 6% to 18% involve the Achilles tendon, and lifetime prevalence for Achilles tendon injury was estimated to be 6% in controls and approximately 50% in former competitive middle- and long-distance runners.[123]

Genetics of Achilles Tendon Injuries

Early reports suggested that blood type (i.e., encoded by the ABO locus located at 9q34) was associated with susceptibility to Achilles tendon injuries.[114,122] This locus is also the site of a more plausible physiologic association with tendon injuries, the alpha 1 type V collagen *(COL5A1)* gene. Follow-up studies have found that variants of this gene were associated with Achilles tendon pathology in South African and Australian populations.[160,217] Several other genes have been tested for association with Achilles tendon injury susceptibility: *TNC,*[159] *COL1A1,*[183] *COL12A1,*[216] *COL14A1,*[216] *TGFB1,*[182] *GDF5,*[182] and *IL1B, IL1RN,* and *IL6*.[218] Despite numerous investigations, insufficient evidence supports clinical utility (i.e., ability to suggest preventive measures or guide the prognosis) for these genetic biomarkers.[211] Identifying genes associated with tendinopathy may help provide insight into tendon pathophysiology.

GENETICS IN DIAGNOSTIC TESTS, TREATMENTS, AND PREVENTIVE MEASURES

PERSONALIZED MEDICINE

Advancements in genomics provide a greater understanding of how interindividual differences relate to disease predisposition and drug responses. Personalized medicine aims to tailor prevention and treatment to an individual's biologic profile. Genome sequencing (from blood or saliva) may be used to test for genetic contributions to disease or disease risk. Gene expression and other omic data can contribute to understanding an individual's risk of disease or response to environmental conditions.

PREDICTIVE MEDICINE

Predictive medicine works to assess probability of disease prior to its onset to minimize the impact on an individual. This effort uses information about an individual's environmental exposures and genetic makeup in association with proteomic and metabolomic biologic markers. Biologic markers may indicate early evidence of disease. Using DNA arrays or sequencing technologies, genetic risk loci can be detected years before disease onset.

Genetic testing may be recommended at different life stages. Prenatal testing, used to identify diseases or conditions in a fetus or embryo, is available to couples with an increased risk of genetic or chromosomal disorders. Tests may be minimally invasive (e.g., ultrasonography, maternal serum analyses, and maternal DNA tests) or may require invasive measures (e.g., needle aspiration for chorionic villus sampling of the placenta). Newborn screening is used to identify genetic disorders that require early treatment. In the United States, all newborns are tested for phenylketonuria and congenital hypothyroidism. Predictive risk testing (e.g., for breast cancer) uses genetic tests and a review of environmental factors to stratify the risk of disease. Diagnostic testing is used to confirm or specify the diagnosis of a particular disease. Carrier genetic testing determines whether one or both parents have a genetic variant that, if present as two copies, results in disease (e.g., cystic fibrosis). Preconception testing may be carried out on sperm and eggs to determine the risk of diseases and specific traits in offspring.

Direct-to-consumer genetic testing kits are available without physician authorization. Predictive approaches are based on probabilities, and are not able to determine with complete certainty that a disease will occur. In the absence of professional input, individuals may misinterpret genetic results.

Pharmacogenomics

Genetic variants influence individual drug responses. In different patients, a drug might have salutary effects, damaging effects, or no effects. Using analyses of multiple genes and epigenetic profiles, pharmacogenomics characterizes how acquired or inherited genetic variations contribute to function, absorption, distribution, metabolism, and elimination of a particular drug.

Rather than using a "one-size-fits-all" approach, pharmacogenomics uses an individual's genomic information to ensure that a medication dose has the greatest degree of effectiveness with minimal adverse effects. In the United States, millions of adverse drug reactions occur, leading to 100,000 deaths each year.[62] Many reactions are secondary to underlying genetic variants, typically found in a small proportion of the population.

Genes associated with pharmacogenomics are classified as pharmacodynamic or pharmacokinetic. *Pharmacodynamic genes* encode protein targets of drugs. These targets are often cell surface receptors, enzymes, or nuclear hormone receptors that modulate normal biologic function (e.g., agonists or antagonists). Genetic variation can alter properties (e.g., chemical or structural qualities) between a drug and its target protein. *Pharmacokinetic genes* encode proteins that influence availability of a drug (i.e., its absorption, distribution, metabolism, or elimination). Due to individual genetic variation, drugs that are processed in the body may be eliminated too quickly or slowly, with potentially deadly results.

As in GWASs, pharmacogenomic responses may be analyzed in a case-control (binary) or quantitative (dose) context. Individuals who exhibit an adverse response (e.g., myopathy after statin treatment) may be genotyped to look for associations. People with particular variants may want to consider alternative treatments based on predicted outcomes.

Pharmacogenomic testing of individuals for clinical care is not common practice. Data to provide molecular information about specific drugs and genes are publicly available (e.g., the Stanford University Pharmacogenomics Knowledge Base [PharmGKC]), but the data should not be used to make definitive decisions. Pharmacogenomic variants indicate the likelihood of a drug's being effective (e.g., a drug may be 90% effective if homozygous for a particular allele, 50% if heterozygous or homozygous for the alternate allele). SNPs in *quantitative trait loci* may explain some proportion of variation in a drug-metabolism trait, and may be used in predictive models of a drug response.

Genes associated with variance in drug metabolism and response include cytochrome P450s (CYP), the vitamin K epoxide reductase complex subunit 1 *(VKORC1),* and thiopurine methyltransferase *(TPMT).* Of the 57 CYP-family genes, *CYP2D6, CYP2C19, CYP2C9, CYP3A4,* and *CYP3A5* account for the metabolism of approximately 80% of currently available prescription drugs.[272] *VKORC1* underlies the pharmacodynamics of the anticoagulant warfarin[236] because warfarin inhibits the *VKORC1* gene product, and *TPMT* is an enzyme associated with metabolic pathways that involve codeine, clopidogrel, tamoxifen, and warfarin.[53]

PERSONALIZED GENOMIC WILDERNESS MEDICINE

Adoption of personalized genomic approaches has limitations, including the uncertainty of clinical applications of associated genetic variants, expense, insufficient expertise to carry out and analyze genomic tests, and ethical questions raised by personalized medicine. This is true for conditions associated with wilderness travel.

Which Genes Should We Test?

Lack of clinical utility is the greatest impediment to using genomic medicine for conditions associated with wilderness travel. Given present knowledge, screening individuals for genetic variants is unlikely to improve patient care. For instance, although variants of the *TIMP3* gene were associated with susceptibility to HAPE in a Japanese population,[121] the association must be independently replicated to ensure validity before the information can be used for screening.

Susceptibility to many environmental stressors is likely complex; the interaction of multiple genetic variants and environmental factors determines one's susceptibility. A single genetic variant is likely to have only a small independent effect on an individual's susceptibility to an environmental condition (e.g., altitude, temperature, UV light) and is unlikely to alter clinical outcomes.

Genetic variants associated with the response to exercise training are better established. Genetic testing is being offered to provide insights into the training responsiveness of individuals,[38,200] as a means of identifying talent in younger athletes,[39,44,194] and as a way of determining susceptibility to sports injuries.[78,83,243]

Is the Test Worth It?

Individuals should not pursue genomic testing for the wilderness conditions discussed above. Even if a disease's genetic cause has been well characterized, testing for most benign conditions, especially those that can be easily avoided (i.e., susceptibility to AMS, which can be prevented by gradual ascent), is unlikely to influence outcomes.

Testing for genetic susceptibility to life-threatening conditions (e.g., HAPE or HACE) could provide greater benefit, but is unlikely to replace universal recommendations of gradual ascent.[142] In rare instances, individuals identified as susceptible to severe AMS, HAPE, or HACE could be excused from high-risk scenarios when proper acclimatization is not possible (e.g., in military efforts or search and rescue deployment).

Who Is Going to Interpret the Genomics Data?

Implementing individual genomic results into medical practice would require a full suite of knowledgeable health care professionals (i.e., physicians, nurses, pharmacists, genetic counselors) to recommend tests, answer questions, and interpret data. Many physicians do not have the necessary training in genomics and are not ready to deliver personalized medicine.[154] Although genetic counselors are trained to perform this role, there are not enough providers to absorb the burden of expanded personalized medicine.[154]

What Are the Ethical Concerns Surrounding Genomic Medicine?

The ethics of genomic medicine are still developing.[155,180] Sequencing an individual's genome provides more information than the average layperson (and perhaps even the best contemporary scientist) can fully appreciate. In addition to information about disease susceptibility and pharmaceutical effectiveness, an individual's genetic sequence contains information (e.g., ancestry, paternity, maternity, disease susceptibility) that many individuals might not want to know or want others to know.

Personalized medicine can identify treatments that are most likely to be successful, ineffective, or potentially detrimental but are likely more costly. Guarding against breaches of confidentiality and genetic discrimination will be constant concerns.

MOVING FORWARD

More than 2000 years ago, Hippocrates stated, "It's far more important to know what person the disease has, than what disease the person has." What is new in personalized medicine is the potential for genomics (and other omics-based technologies) to intimately describe molecular differences among individuals to personalize suitable treatments. With these tools, "what person the disease has" implies that a specific, molecular meaning can be determined.

Although adopting genomic medicine in the clinic will not be easy, this work is already informing medical care. Pearson and Manolio[172] state, "The primary use for GWA studies for the foreseeable future is likely to be in investigation of biologic pathways of disease causation and normal health and development." Genomics (and other omics-based research) can offer great insight into pathophysiologic processes, and can lead to better treatment, even if this treatment is not personalized. Omics technologies are already improving our understanding of high-altitude adaptation, chronic altitude illness, and HAPE. These processes and conditions likely will be further elucidated through the use of various omics-based methods.

Given the difficulties associated with investigating conditions most relevant to wilderness medicine, application of genomic medicine to this field will take time. Higher-quality genomics studies are needed to elucidate genetic variants associated with each condition. Answering whether genomic testing adds sufficient new data (beyond known risk factors) to justify the costs of screening will follow. A better understanding of the physiologic mechanisms underpinning each condition is necessary. Omics-based research can help provide this information.

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