It is Thanksgiving dinner in Akron, Ohio. Aunt Roberta has just returned from her IPM (Integrated Pest Management) field sites near Timbuktu in Mali, Asmara in Eritrea, and Entebbe in eastern Uganda. She is spending the brief holiday with her niece and nephew and their families, as usual. Aunt Roberta, generally quite a lively person, was subdued when she arrived this year. She had thought she had a mild bout of malaria when she was at her last field site in Uganda. But, she said, she had recovered completely from that. However, since she arrived in Akron a few days ago, she said she had been feeling poorly. She said it felt like delayed jet lag. At Thanksgiving dinner, her niece and nephew and their children noticed that Aunt Roberta could not follow the conversation and had forgotten to pass the peas even though asked twice. By the time the pumpkin pie was served, Aunt Roberta was slumped in her chair. Her niece tried to rouse her, but it was clear that she was losing consciousness. The niece and nephew rushed her to the emergency room. There, her family mentioned only that "Aunt Roberta just isn't herself." The physician and nurses neglected to ask questions that would elicit information about where she had been traveling. In the emergency room, Aunt Roberta now is forgetting the names of her niece and nephew. She begins to hallucinate about light trap collections but does not remember to mention her recent overseas travels and their locations. While in the emergency room, her blood smears and serum profiles are mildly abnormal (i.e., elevated liver enzymes, thrombocytopenia [low platelets], and elevated white blood cells with normocytic anemia). Her EKG (electrocardiogram) shows a few premature beats but otherwise is normal with some delayed conduction. Her physical examination is written up describing her as a 42-year-old white female with altered mental status and stupor, slight purpura on her ankles and abdomen, slight tremor in the face, and a low grade fever. The emergency room staff is puzzled. Meningitis is the tentative diagnosis and a lumbar puncture is performed. The cerebrospinal fluid (CSF) has mildly elevated white blood cells (neutrophils), elevated total protein, and negative Gram stain. Aunt Roberta is admitted to the hospital with a diagnosis of meningitis, possibly bacterial, and placed on a regime of i.v. (intravenous) antibiotics, seftriaxone, and ampicillin. However, she continues to have decreased mental status and the CSF bacterial cultures are negative. Viral and fungal cultures of her CSF were sent off and returned negative. Aunt Roberta now is in a coma and after an apneic episode she is intubated. She is bleeding from all intravenous line sites. Her blood pressure drops, and Aunt Roberta expires seven days after Thanksgiving Day. A postmortem examination of her CSF finds that Trypanosoma brucei rhodesiense *Stephens et Fantham was present.*

The Doctor Is In: Medical-Veterinary Entomology Clinics for Undergraduates

Florence V. Dunkel, Patricia M. Denke, Alexander J. Dunkel, and Anne-Marie Dunkel Pfaff

Aunt Roberta obviously was bitten by one or more tsetse flies in Uganda, which she probably thought was not worth mentioning. She had had tsetse bites during each visit for the past 14 years and could have encountered the flies at either the Mali site or the Uganda site. This year, however, she must have been bitten by flies at the Uganda site (of the three sites she visited this year, it is only Uganda that is located in the range of this protozoan) and at least one of them was carrying the trypanosome, *T. brucei rhodesiense,* which causes acute (or East African) Sleeping Sickness. Unfortunately, the trypanosomes, probably very few, that were still appearing in the blood were missed by the medical technologists in the laboratory during their differential analysis of the blood smears. Undetected, they passed the blood-brain barrier and entered the central nervous system shortly after Thanksgiving Day. An intravenous course of medication on Thanksgiving Day might have saved Aunt Roberta, but it should have been an antiprotozoan agent specifically for the trypanosome, not the antibiotic chosen for bacterial meningitis. Furthermore, the window of treatment opportunity closed shortly after Thanksgiving Day. Once in the central nervous system, trypanosomes are difficult to reach with antibiotics, leaving only arsenic and other more toxic, less effective, compounds. Missing was that one piece of information that would have saved Aunt Roberta's life: Where had this patient been in the past few weeks? Aunt Roberta would probably be alive today had someone in her environment asked the right arthropod-vector question. There have only been 15 cases of acute African Sleeping Sickness diagnosed in the Americas since 1967. Nearly all ended the same as that of the fictitious Aunt Roberta: misdiagnosis and death (Quinn 1992).

A Dramatic Learning Experience

Changes in vector ranges are bringing the possibility of new diseases to areas that were previously free of the disease (Garrett 1994), and mutations in both disease organisms (e.g., dengue hemorrhagic fever and *Plasmodium falciparum* Welch), and arthropod vectors are making it more difficult to use chemical prophylaxis effectively. Even in areas where vector-borne diseases have been endemic in wild animal populations for years, increased contact between human and wild animal populations are leading to disease transmission (Robertson et al. 1996) such as the case in Billings, MT, where a taxidermist contracted plague from a bobcat and died (Repanshek 1992). With increased air travel, people no longer are aware necessarily of the risks they are taking or what they may be bringing back with them. Thus, medical personnel may be faced with diseases unheard of locally.

We developed medical-veterinary entomology clinic simulations to create a dramatic learning experience that undergraduate students from any major would find thought-provoking and to provide an effective way to assimilate the key issues in this complex set of information. We based the clinics on the fact that insects and other arthropods can, by their actions and their associated microorganisms, threaten the lives of humans and their companion and domestic animals. Across disciplines, undergraduates are fascinated by medical-veterinary topics. This fascination often is squelched by requirements for memorization of scientific names, life cycles, and reservoirs. In our 3-credit "Issues of Insects and Human Society" course at Montana State University (MSU), the complex topic of arthropod-vectored diseases must be covered in 9 of the 39 total class hours. Due to the increasing popularity of similar human society courses in U.S. colleges and universities, lectures may be presented to as many as 500 students per semester with no laboratory or recitation (Fell, Stoffolano, Matthews, and Turpin, personal communication). Without laboratory or recitation formats, medical-veterinary entomology subjects are even more difficult to assimilate. Since 1991, at MSU, we have designated three of the nine hours for the medical-veterinary entomology unit as "recitation/laboratory."

To speed up the students' assimilation of the medical-veterinary information and their understanding of the issues, we concentrate on "real-life" diagnostic situations that could occur at these "clinics" around the world. We transform the room in which we hold the laboratory into five mini-clinics that are "located" at five sites on four continents. We focus on patients in real situations with arthropod-transmitted diseases. To make an accurate and timely diagnosis and, perhaps, "save the patient's life," the student previously must have assimilated and organized facts regarding arthropod vectors and the reservoir animals (habitat, biogeography, and even circadian rhythms), life cycles of the disease-causing microorganisms, and physical and/or laboratory diagnostic symptoms into individual parcels of information. To succeed in the clinic environment, students must combine these parcels into a correct diagnosis.

Learning Objectives. Six years ago, we developed the "clinics" for a university-wide Global/Multicultural Core course. Since then, we have incorporated the clinics as an integral part of the overall learning objectives of the course, which are designed for all students including nonbiology majors (e.g., engineering, architecture, music, art, literature, computer science, history). The overall learning objectives are to: (1) acquire an understanding of how scientific data are collected and translated into useful information, and how this information creates desirable change; (2) acquire an understanding of the magnitude of the effects of insects in day-to-day life; (3) obtain information on insect-related issues that potentially affect individuals, families, living spaces, and businesses; and (4) evaluate increasingly more complex issues related to insects and make effective decisions about these issues in a mentoring environment. The specific learning objectives of the Medical/Veterinary Clinic module are to acquire an understanding of four concepts: (1) it is possible to fall ill from arthropod-transmitted diseases anywhere in the world, depending on where the patient has traveled recently; (2) these diseases can be contracted from vectors throughout the world, although often in specific habitats or obtained from vectors that have a limited range (e.g., African sleeping sickness [found 15° latitude North to 15° latitude South on the African continent, and within those limits in specific microhabitats]); (3) there are certain "at risk" occupations associated with arthropod-vectored diseases (e.g., wildlife rehabilitation, animal control, international collaborative research); and (4) there are certain "at risk" life styles associated with arthropod-vectored diseases (e.g., foreign travel, wild game hunting, hiking, having house pets that are allowed outside).

Targeted Diseases. Human malaria was chosen as one of the key diseases for these clinics because it causes death or debilitation for millions of people each year (an average of 114 children die per hour from malaria in Africa alone [Cowley et al. 1993]) and has played a major role in U.S. history affecting settlement of the eastern United States (1600s–1900s) and outcomes of the U.S. Civil War and Vietnam Conflict (Miller 1997). African Sleeping Sickness (humans) and Nagana (nonhuman mammals) were chosen because of the severe effect they have had on the agricultural development and the history of colonization in subsaharan Africa (Betts 1985, Cattand 1988). Bubonic plague (and related pneumonic plague) in humans and cats was chosen because of the impact it has had on world history (Betts 1985); the current risks it poses to veterinarians, cat owners, and any people in plague endemic areas (such as areas in or near the Rocky Mountains of the United States and other parts of the world); and because it is highly contagious and acutely fatal if not treated promptly. Rocky Mountain Spotted Fever and Lyme disease were chosen because of the risk they pose to people choosing wilderness sports. Rocky Mountain Spotted Fever is acutely fatal if not treated. Lyme disease is a problem because of the real possibility that many students and their companion animals will be exposed, and because it is severely debilitating if not diagnosed and treated promptly. Heartworm disease in dogs and cats, Equine encephalitis in humans and horses, Chagas' Disease or South American Sleeping Sickness, Elephantiasis, River Blindness, Yellow Fever, and Dengue Fever/Dengue Hemorrhagic Fever also were chosen because of specific reasons similar to those described previously (National Public Television 1987).

Clinic Locations. Because specific arthropod habitat and geographic range are important for transmission of these diseases, each clinic location was chosen to be near a specific concentration of a disease reservoir. Because one of the learning objectives of the clinic is to understand the dissemination potential of airplane travel, each clinic was located near an airport, which allowed us to use any of the eight diseases at each clinic. We chose New York City because of its large number of international travelers and because the northeast United States has endemic Lyme disease. Crow Agency, a small town, was chosen because it is in Montana and near a plague reservoir area. The relative proximity of Crow Agency to Billings, MT, creates a "trick" location, because otherwise, this small town, Crow Agency, is rather remote. On the day of the clinic, some students choose Crow Agency because they think it is a nontropical location where they may see only a few, if any, arthropod-vectored diseases. In Kigali, Rwanda, malaria reservoirs are common in the city, and there is an East African (acute) sleeping sickness reservoir nearby. In Bamako, Mali (West Africa), malaria reservoirs are common, and reservoirs of West African (chronic) sleeping sickness are nearby. Guangzhou, People's Republic of China, is in a nonmalaria zone but near Hainan Island where there *is* a risk of obtaining malaria. Bogota, Columbia, is in an area where inhabitants are at risk of obtaining Chagas' disease, malaria, and river blindness.

Setting the Stage. To prepare for this part of the course, students are given access to several types of resources (Fig. 1) including: (1) a 55-minute introductory video, (2) five 50-minute interactive lectures, (3) library reserve readings, and (4) access to a six-hour discovery laboratory. The introductory video is a NOVA production (National Public Television 1987) entitled "Conquest of the Parasites" that presents information on four diseases, three of which are insect-vectored (malaria, African sleeping sickness, and river blindness). The video summarizes progress through the early 1980s on the development of substitutes for DDT, use of vaccines for diseases such as malaria with multiantigenic problems, and the use of natural products such as ivermectin from fungal extracts. Each lecture contains a verbal description and a role-played enactment of the vector and disease organism cycles using a unified diagram that we have drawn specifically for the course and provided in the course workbook (Dunkel 1999). Each lecture also contains a visit (via slides or video) to the reservoir habitat of each of the diseases and focuses specifically on a patient who has had, or is ill from, one of these diseases. This patient focus may be a personal statement from the professor and/or a class member (who has survived malaria), a slide-illustrated vignette similar to that of Aunt Roberta, short videos of a patient being examined by a physician or veterinarian, a reading from world literature (*The Plague* [1948] by the existentialist author, Albert Camus), local newspaper accounts of plague outbreak in India or a taxidermist dying of plague in Billings (Repanshek 1992), or an historical account of a graduate student at Montana State University who died in 1922 from Rocky Mountain spotted fever during his field studies on the disease. During this preparation period for the clinics, students are encouraged to develop their own individual diagnostic guide for the eight core diseases used in the clinics and to become familiar with the four additional, related diseases. Reserve readings are focused on issues such as the emergence of new, more virulent, arthropod-borne diseases (Garrett 1994), rural development and incidence of arthropod-borne diseases (Betts 1985, Cattand 1988), and the circuitous search for a malaria vaccine (Kolata 1984, Marshall 1992, Maurice 1995). Questions not answered during the interactive lectures or in reserve library readings are answered during the six hours of "discovery." In the "Discovery Lab" (Fig. 2A), students have access to a library of medical-veterinary entomology texts and are able to examine specimens of the vectors (live, pinned, or on slides) and microscope slides or electron micrographs of the disease-causing organisms. At the same time, students have access to the professor and teaching assistants for answers to questions and verification of associations they have derived from the separate sets of information they have discovered during this event. Students are encouraged to work in teams and use the matrix form in their workbook (Dunkel 1999) to guide them in organizing information. We use the inquiry method of teaching whenever possible (i.e., questions are answered by questions).

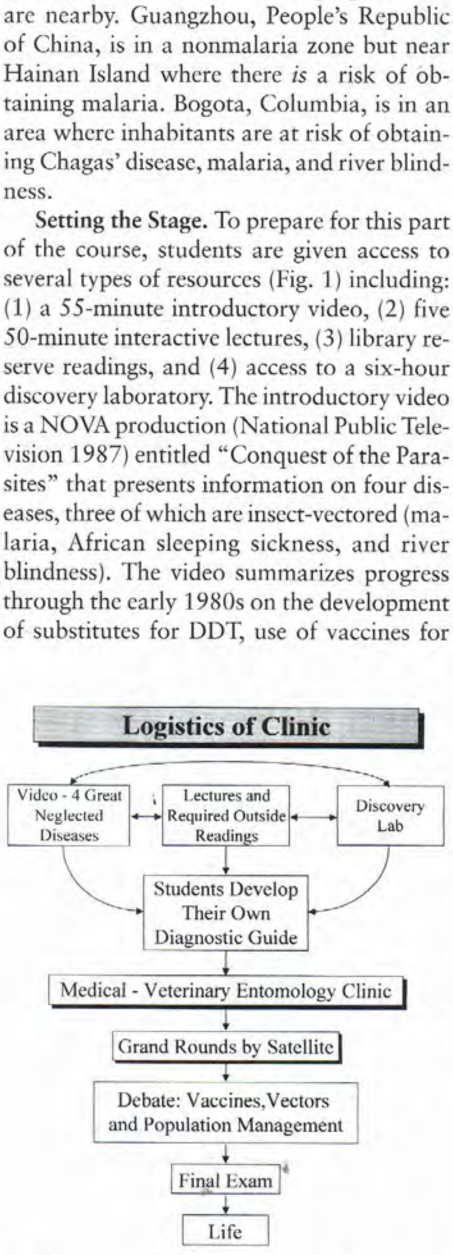

Fig. 1. Diagram of the logistics of student preparation for the clinics and follow-up after the clinical experience.

Fig. 2A. The Discovery Laboratory resource station for African (acute eastern and chronic western human forms, and nagana) sleeping sickness...

Clinic Construction. On the day of the clinic, students in each laboratory session

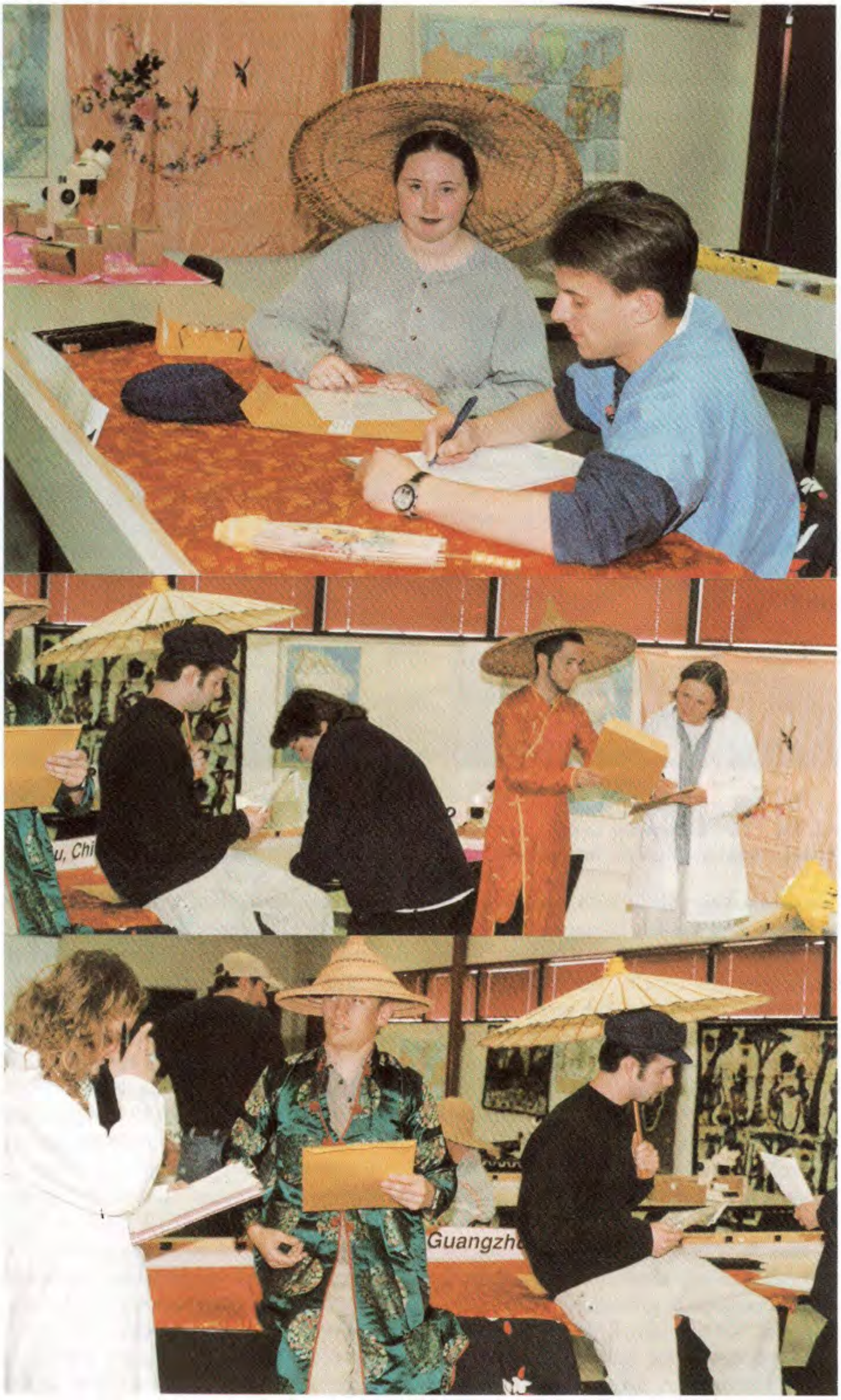

Fig. 2B. ...Students role-playing physicians, veterinarians, and patients in the clinic in Guangzhou, China...

(approximately, 20 per laboratory) are split into two groups. The first half is ushered into the clinic area, a large laboratory classroom divided into five regions with props including authentic textiles and other materials to create the ambience of regional "waiting rooms and examining rooms" (Figs. 2B–D). The "patients/pet owners/relative or friend of patient" wear articles of traditional clothing for the region. The students are given a packet that defines the patient so they can become familiar with the patient's "case history" (Figs. 2B and C). Patients who "arrive" at these clinics include young children and adults, dogs, cats, and horses. Facilitators circulate through the clinic "patient waiting rooms" answering questions about procedures for the role-play (Fig. 2C).

Meanwhile, in another room, we meet with the second half of the students who will be the first "physicians and veterinarians" for that laboratory session. "M.D./D.V.M.s" are given clipboards with patient history and clinic analysis forms and white coats or jackets to identify their role. The "M.D./D.V.M.s" are encouraged to use the matrices they developed earlier in this module.

Conducting the Clinics. After the M.D./D.V.M. greets the patient, or companion of the patient, in the clinic and hears her/his symptoms and other relevant and irrelevant information, the M.D./D.V.M. asks for any examination information (Fig. 2B). If a skin rash or bubo is typical of that particular patient's condition, a laminated photo of the condition will be in the patient's packet for the patient or companion to give to the M.D./D.V.M. With notes taken on the physical exam and patient history, the M.D./D.V.M. then proceeds to the "laboratory" corner of the clinic (Fig. 2D). Here, there is a microscope and a box labeled with the patient's clinic number (one box per patient). Each box contains a key specimen from that patient. This may be a prepared microscope slide of a suspected vector brought in with the patient or a laminated photomicrograph of an organism found in the patient's blood or spinal fluid. The M.D./D.V.M. then fills out a laboratory report and makes a final diagnosis of the patient's illness. In doing so, the M.D./D.V.M. may consult her/his diagnosis matrix developed during clinic preparation.

Vignettes developed for the clinics were constructed with authentic names and actual places where the authors have lived or visited. The clinic vignettes are shorter than the teaching vignettes used in the discovery part of this clinic-based module. For example, one of the clinic vignettes might be as follows:

> At the small clinic located in Crow Agency, Montana, a young woman in her late twenties appears anxious and says, "I have brought my daughter, Rachael Brown White Antelope, to the clinic because she is shaking all over. We brought her in an ambulance because she cannot walk. Rachael is six years old. She was feeling fine until just today, about 5 p.m." When asked by the physician if Rachael had done anything unusual in the last few weeks, her mom replies that, "Two weeks ago, our family went to southern Louisiana where my parents live. We thought Rachael would enjoy being in a different part of the U.S.A. and would enjoy seeing where her grandparents live. It rained a

lot and was pretty wet while we were there. At the end of the day, when the rains would stop, we walked along the road, beside Lake Ponchatrain. I noticed that the mosquitoes were quite bad, just at sunset, before it became really dark."

Young Rachael and her mother have presented a typical history of malaria. Rachael, of course, did not encounter the anopheline vector in Montana where she fell ill, but the astute physician did ask for recent history and was, probably, aware that the range of malaria-carrying *Anopheles* spp. includes Louisiana. Although Rachael's mother did not include much unrelated information, many of the 40 patients do. The M.D./D.V.M. must sift and winnow the important from the extraneous.

There are 40 patient vignettes with eight possible diseases at each of the five clinics. In any one laboratory period, there will be two to six students role-playing at any one clinic. Each of the possible patients has one of the eight diseases that the students are required to identify. Although each "clinician" must be prepared to diagnose all eight diseases, they actually will see only two patients (and therefore only two diseases). Each clinician, however, will see two different patients.

Grand Rounds by "Satellite Link." Immediately after all patients are "seen," we hold "Grand Rounds by Satellite." We have selected this technique from the model of teaching hospitals in the United States, where there are medical-veterinary students and M.D./D.V.M.s in advanced training. Some of the students, interns residents, and attending (professor rank) physicians-veterinarians may be located at outlying clinics. Periodically, usually once a week, Grand Rounds are held for these health-care professionals. For this event, students, house staff, and attending physicians-veterinarians present difficult-to-diagnose patients or unusual cases. This presentation may occur on the hospital floor (patients' rooms) or in a conference room. If there is an affiliated remote clinic, this two-way presentation may be transmitted by a satellite link.

Because our "clinics" are located on four continents, we must gather our "health care professionals" for "grand rounds by virtual satellite link." The "clinic" is a one-on-one activity, whereas "grand rounds" involve one person presenting to approximately 20 other students. Several students, generally from several "clinics," are chosen to present their patients. Students who present are chosen by the "attending physician/veterinarians" (i.e., the professor and teaching assistants) (Fig. 2C). This choice often is determined by the accuracy of the diagnosis. Students who make an incorrect diagnosis usually are asked to present that patient at grand rounds. When the same disease is presented by students at more than one clinic, a "teachable moment" often occurs. Although we have, in a 50-minute period, only 10 minutes alloted to grand rounds, these usually are 10 minutes packed with "teachable moments" (e.g., when a student first understands that clinic location does not, in this age of air travel, determine which diseases may be encountered in the clinic). Students also may find that, earlier, they had not listened carefully, especially when the patient was giving the "clue" to where they might have encountered the suspected arthropod vector.

Final Exam. In the final exam, students again are asked to "see" and "diagnose" three patients, this time in a large hospital (human or veterinary) emergency room instead of a remote or neighborhood walk-in clinic. This hospital could be anywhere in the world and always is in a different city, often a country different from the one(s) in which the clinics where the students had "worked" previously were located. Students then are asked to imagine that they are the only physician/veterinarian in the hospital and the emergency room has a small nursing/assistant staff. In their final exam, they must make triage decisions (i.e., they must decide which one of the three patients with arthropod-vectored diseases is in a life-threatening situation and must receive the immediate focus of the emergency-room staff). Then, students must decide which of the remaining two patients must be seen next and which patient can be seen after the first two have been stabilized. Finally, students must defend each of their choices.

Evaluation. In 1999, students were asked to provide anonymous, written responses to the following question: "What part of this clinic experience do you think was the most valuable to your learning?" Ninety percent of the students responded and their comments were similar to the following specific student quotes: "I visually saw the symptoms that I needed to watch for and played a real doctor's role;" "dressing up to experi-

Fig. 2C. ...Teaching assistant role playing the resident medical staff and student role playing a patient in the clinic located in Kigali, Rwanda and...

Fig. 2D. ...Students role-playing medical entomologists and medical technologists in the clinical laboratory in Kigali, Rwanda.

ence the location;" "the real live experience—when you apply research (meaning perhaps their study for the quiz, which actually was the clinic) to experience, the learning process is more solid, you do not just remember for a couple of days, but possibly for a lifetime."

Correct diagnosis of each of the 38 patients used in 1999 required assimilation of one to three of the four learning objectives for this medical veterinary portion of the course. Students, in their responses in the clinic, demonstrated a high understanding in 85, 80, and 86%, respectively, of objectives 1, 2, and 4. Seventy per cent of responses showed a high understanding of objective 3 (i.e., that there are certain at-risk professions for arthropod-borne diseases). Using the Lickert scale (Angelo and Cross 1993) to assess student-perceived value of the experience, students rated the clinic activity on a 1–5 scale at 4.5 (5 = outstanding) (n = 46) in its ability to enhance their understanding of becoming ill from many localized arthropod-transmitted diseases anywhere in the world, depending on where one has traveled recently. In 1999, of the 51 "physicians/veterinarians" who made a total of 102 patient diagnoses (38 different patients), only 3.9% were misdiagnosed. This is amazing considering that of these 51 students, 25% were freshmen and 79% of the declared or intended majors of all the students were in engineering, physics, architecture, sociology, earth science, business management, and other nonbiology/premed/wildlife management areas.

Summary and Conclusions

The important functions of these clinics are to teach students that diseases transmitted by arthropods exist, *and* we need to learn to accept this; however, death is not inevitable and certainly should not result from misdiagnosis. This clinic model may help undergraduate students understand that there are risks associated with activities such as deer hunting, hiking, having house cats, traveling in the tropics or remote areas of the temperate world, and being a veterinarian. These risks can, however, be managed and, for the most part, avoided.

Activities we chose for more rapid assimilation of medical-veterinary entomology emphasized discovery, using hands-on activities, learning independently and with groups, and self-expression (development of student's own diagnosis plan). By placing students in a role-playing situation, we strengthened their associations between the parcels of information and facilitated their analytical thinking. This combination of activities was developed to achieve our learning objectives, which included developing good listening skills and understanding complex interrelationships of medical-veterinary entomology issues. These types of learning experiences apply from kindergarten (Wangberg and Wangberg 1998) through graduate courses in entomology (National Research Council 1996).

Although we have not statistically tested retention/understanding of information in conventional lecture-laboratory examinations versus the clinic/grand-rounds method of teaching medical-veterinary entomology, we do know this portion was the most difficult part of the course for students using conventional lecture/laboratory methods. With this clinic-based approach in use since 1993, students have garnered better grades and achieved the learning objectives for this section of the course. In both informal and formal student evaluations, this is the students' favorite part of the course. Many students are visual learners, and complex names and life cycles are a "new language." In this series of learning experiences, images are available via slide series, video segments, live and preserved specimens, and role-playing with "diagnoses and saving lives" as the goal.

With the clinic module, we believe students gained a better appreciation of how to minimize risk from arthropod-vectored diseases in their own lives and were able to assess better the risk of the illness being life-threatening. We suggest this method of "clinics throughout the world" and "grand rounds by satellite" can be adapted for any course with a section in Medical-Veterinary Entomology, whether it is at the undergraduate, graduate, or professional school level.

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