RODERICK E. McGREW

ENCYCLOPEDIA OF MEDICAL HISTORY

Encyclopedia of Medical History

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with the collaboration of

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Preface

The purpose of the *Encyclopedia of Medical History* is to provide an easily accessible historical treatment of important medical topics which will engage the general reader while providing students of both history and medicine with a fund of information complementary to their specialties. Each entry has been conceived as an independent essay covering the stated topic chronologically. There are no summary or definitional entries as such, and there are no biographical articles. Individuals' contributions to medical science are discussed as part of the evolution of techniques, ideas, or institutions. The index provides a guide with page references and vital dates for the more important personages mentioned.

Each essay has a list of additional readings appended. The number of titles cited varies from subject to subject with the prime variable being the amount of historical work which has been done on the subject. At the very least the reader will find these recommendations useful for acquiring more detailed information than the entry can provide. Where there has been substantial recent historical writing or where the subject may be controversial, the reading lists are more extensive and detailed, including references to monographic literature and specialized articles. Even so, the additional readings are intended only as a supplement; they are in no sense a systematic guide to bibliography or research. Readers who require detailed current bibliographical data, including materials not available in English, may consult the U.S. Army Medical Library, *Index Catalogue*, ser. 1, 2, 3, 4, 1880–1948; the U.S. Department of Health, Education, and Welfare: National Library of Medicine, *Bibliography of the History of Medicine*, 1965–1984; and the Wellcome Institute of the History of Medi-

cine, *Current Work in the History of Medicine: An International Bibliography*, quarterly, London, 1954–1984. In addition, reviews and review essays in the *Bulletin of the History of Medicine*, the *Journal of the History of Medicine and Allied Sciences*, and *Medical History*, to mention only three leading and easily accessible journals, provide discriminating judgments and are invaluable for following the current evolution of the field.

The author wishes to acknowledge the assistance he has received in preparing this book. Margaret P. McGrew, the author's collaborator, deserves the most particular recognition. Quite literally, without her help, the book could not have been done. Robert Rosenbaum, formerly of McGraw-Hill, proposed the idea for the book and was most helpful and supportive during the early writing phase. Thomas Quinn, senior editor at McGraw-Hill, has been enthusiastic and understanding while guiding the book through its later stages. Susan Killikelly has been an efficient, responsible, and cooperative editing supervisor. Dr. Nancy Frieden, Prof. Terry Parssinen, and Robin Price made useful suggestions and shared their work on the development of the medical profession, drugs and drug abuse, and hydropathy and irregular medicine. Especially warm recognition is owed to the administration and staff of the Wellcome Institute and Library for the History of Medicine, Euston Road, London. Unfailingly courteous, cooperative, and efficient, they gave every assistance during the 16 months the author and his collaborator worked in their collections. Temple University made it possible for the author to devote the academic year 1979–1980 to the project by granting him a leave of absence. The author accepts full responsibility for whatever errors of fact or judgment the book contains.

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Abortion

Abortion is the destruction or loss of a fetus or fertilized ovum before it is sufficiently developed to survive outside the uterus. In general, abortions are of two kinds: induced or spontaneous. Depending on the system of laws in a society, induced abortion may be legal or illegal, while in some societies even spontaneous abortion as a result of accident or neglect can result in punishment for the person held responsible, usually the mother.

There is no clear pattern in history concerning the morality or legality of induced abortions. Primitive peoples, faced with the need to limit population growth as a matter of survival, regularly practiced induced abortion. Over time, however, and as they advanced in civilization, those same peoples often would not permit abortions, and they eventually came to consider the practice immoral. The presumption is that an advancing society not only could support new lives but also needed them to continue growth. Many ancient cultures, including the Hittite, Sumerian, Assyrian, and Persian, punished any person found guilty of striking a pregnant woman and thereby causing her to abort. Self-induced abortion was punished even more severely. The Assyrian codes of about 1500 B.C., for example, decreed impaling as the punishment for such a crime.

Opinion was divided in the Greek world. Infanticide was regularly practiced by exposing newborns, particularly females, to the elements, and both Plato and Aristotle supported abortion for eugenic as well as demographic reasons. The Hippocratic oath, however, declared against aiding abortion, a position entirely consistent with the Hippocratic view that the physician's function is to assist nature and protect life.

Roman regulations appeared to be antiabortion. A law of A.D. 85 provided punishments for those who sold abortifacients rather than for the women who bought them, while the *Corpus Juris Civilis* (A.D. 533–534) of Justinian the Great prohibited abortion on the grounds that it endangered a mother's life while impinging on the father's rights and the rights of society. These laws, which held abortion socially harmful, did not, in fact, affect the majority of abortions which were carried out within the family. Jewish practice, which was derived from the Hebrew Old Testament and the Talmud, often ruled against abortion for any reason except a threat to the health or life of the mother. However, there was no specific prohibition against abortions.

Christian doctrine firmly opposed abortion, and the religious prohibitions became legal rules which were enforced throughout the Christian world. The emphasis fell on the rights of the unborn child, whose gift of life was believed to come from God rather than the biological father or mother. No attention was given to the rights of parents or society. Revulsion against abortion and the introduction of laws to prevent its practice have been characteristic of both premodern and modern western societies. Nevertheless, abortions have been regularly performed regardless of the law, though the illegal aspect vastly increased the risks of injury and death to the mother.

In the second half of the twentieth century, the conviction has grown that people should be free to decide whether they will have children or not. Family planning and the use of contraception were accepted long before abortion was, though not by the Roman Catholic church, and in the years since World War II, many legal barriers to abortion have been lowered. The reasons tend to be economic, demographic, and ethical, with the need to hold population growth stable leading the way. The claim that women should be free to control their own bodies has been vociferously put forth in advanced western societies, while the social costs of unwanted children have furnished powerful arguments in favor of abortion in poor and wealthy societies alike. Japan has permitted abortions since 1948, the Soviet Union legalized abortions in 1955, and the People's Republic of China turned to abortion as a means of population control in 1957. Great Britain relaxed its abortion laws in the 1960s, India has promoted legal abortion as well as sterilization for population control since 1971, and in 1973, the U.S. Supreme Court invalidated most state laws making abortion illegal. By the 1970s, 27 countries with 58 percent of the world's population had legalized abortion.

There have been serious second thoughts on the use of abortion as a means of population control. For example, in the Soviet Union, where abortion appears to have become more common than contraception, demographic and mortality studies indicate growing public health problems owing to

the frequency of abortions. The problems are compounded by dietary deficiencies and alcoholism. An unexpectedly sharp increase in Soviet mortality rates in part correlates with the high frequency of abortions.

In western countries, most notably the United States, strong resistance on religious principles and on the basis of what is called the "right to life" has made abortion one of the most volatile issues in politics. Nor has the Catholic church abated its resistance to abortion or to contraceptives. Advocates of population control find themselves on the defensive, though their arguments gain strength as new and terrible famines are predicted for Africa as a consequence of too rapid population growth, while China's stringent birth control policies have begun to reduce the rate of population growth. Faced with dwindling resources, even the richest societies recognize the desirability of limiting population growth. But the question of legal abortion as a means to that or other social ends remains highly controversial.

Since abortion techniques are standard and reasonably safe under proper clinical control, medicine has had little to say in this debate, even though the physiological and psychological consequences of a fulfilled pregnancy or its termination may be severe. The issue has been left to politicians and legal experts, moralists, theologians, sociologists, and demographers. Abortion has been discussed in terms of moral absolutes and in an atmosphere of fevered confrontation rather than in a context of social health.

ADDITIONAL READINGS: Dan J. Callahan, *Abortion Law: Choice and Morality*, New York, 1978; Henry P. David (ed.), *Abortion Research: International Experience*, Lexington, Mass., Toronto, London, 1974; George Devereux, *A Study of Abortion in Primitive Societies*, London, 1960; David Granfield, *The Abortion Decision*, New York, 1969; Luke T. Lee, "A Brief Survey of the Abortion Laws of the Five Largest Countries," *Population Report*, ser. F, 1 (April 1973); James C. Mohr, *Abortion in America: The Origins and Evolution of National Policy, 1800–1900*, New York, 1978; John T. Noonan, *The Morality of Abortion: Legal and Historical Perspective*, Cambridge, Mass., 1970; Harold Rosen (ed.), *Abortion in America: Medical, Psychiatric, Legal, Anthropological and Religious Considerations*, Boston, 1967; Patricia Steinhoff and Milton Diamond, *Abortion Politics: The Hawaii Experience*, Honolulu, 1977.

See also: GYNECOLOGY.

Acupuncture

Acupuncture is a medical technique that originated in China more than 2500 years ago. It is the most characteristic treatment of traditional Chinese medicine (q.v.) and has in recent years been enjoying a revival in China while attracting interest in the west. The procedure involves inserting fine metal needles one-half to several inches in length into the skin. The needles, which in some cases are driven in with great force and in others are inserted gently, are set at different depths, while the point of insertion is of particular importance. The oldest existing catalog of insertion points, the section called *"Ling shu"* in the *Huang di nei jing su wen (The Yellow Emperor's Classic of Internal Medicine)*, dates from about 100 B.C., but the points are named in an earlier collection called *He Yi's Cases* (ca. 540 B.C.). There were 360 such points in the second century. A total of 650 (some authorities say 800) loci have been identified to date. Once inserted, the needles are twirled and vibrated. A modern acupuncturist may use a battery-powered device to generate electrical stimulation.

The physiology of acupuncture rests on the Taoist doctrine that the life force (*Qi*), or energy, circulates through all the body's organs. Balance is maintained and health preserved by the interaction of two forms of energy, called yin and yang. Yin is described as feminine, dark, moist, and negative; yang, the masculine principle, is positive, dry, and bright. The acupuncture points are located on 14 lines or meridians which run the length of the body, and certain points on those meridians "control" certain physical conditions. All disease is the result of imbalance in the energy flow in the body. Pain or disease is the manifestation of imbalance, and acupuncture needles introduce a restorative and balancing *Qi*.

Though the connection between Taoism and acupuncture is clear, it is not known how acupuncture originated. It is speculated that the technique was developed in connection with studies of pain, and it may be that acupuncture is a practical application of the principle of referred pain, the tendency for a condition in one part of the body to generate pain in another. Certainly acupuncture was a specific which was supposed

to relieve pain, and it was and is used for anesthetic purposes at childbirth and for some forms of surgery. Occasionally, acupuncture is used in combination with moxibustion (burning a pinch of mugwort or Chinese wormwood on the skin and rubbing the ash into the blister), and it is used more commonly with drug or herbal treatments. As an anesthetic, acupuncture has no aftereffects, and it is considered therapeutic for hay fever and headache, for certain types of blindness, and for arthritis, diarrhea, and hypertension. Some Chinese physicians believe that acupuncture can affect certain infectious diseases, sciatica, and rheumatism.

Many westerners who have had acupuncture in the People's Republic of China have been astounded by the results, while the technique has won followers in the United States as an alternative to scientific medicine. Medical researchers seeking to explain how acupuncture gives the good effect it does have noted that the insertion points correspond to places on the skin with low electrical resistance. This has led to the idea that acupuncture may influence the autonomic nervous system or stimulate the production of antibodies by the reticular endothelial system. Other suggestions include a neurosecretory effect resulting in a rise in cortisone production, and a direct influence on the pituitary gland. In China and Japan, medical researchers using advanced biochemical and physiological ideas are continuing to study what happens under acupuncture. In 1974, the National Institutes of Health agreed to a study of acupuncture as a possible management technique for chronic pain from cancer, arthritis, and neuralgia.

In the United States, though medical opinion is generally hostile, acupuncture is being used for pain relief and anesthesia. Though scientific medicine has not yet succeeded in discovering what acupuncture really does, the results are sufficiently impressive for the institutional establishment to want to have the treatment available. Acupuncture provides evidence that, while traditional explanations for the way procedures are supposed to work are often fanciful, the treatment itself may succeed at least as often as it fails. Valueless or dangerous treatments are less likely to survive than those which work, if only part of the time. Although western science cannot explain it, acupuncture has a long history of successful use.

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See also CHINESE MEDICINE.

African Trypanosomiasis

African Sleeping Sickness; Nagana

Trypanosomiasis is a disease of great antiquity to which both animals and humans are susceptible. In prehistoric times, African trypanosomiasis played an important role in determining the distribution of ground-dwelling primates, including hominoids, by creating zones in which species susceptible to the disease could not exist. Later in the evolutionary process, other factors became important in determining whether susceptible species could exist with trypanosomiasis. These factors included birthrate, levels of health, and the ability to devise avoidance procedures to minimize contact with the disease. In historic times, African trypanosomiasis limited the areas open for cultural development and had a direct influence on the kinds and levels of civilization possible south of the Sahara. This influence has affected both native societies and colonizers.

Disease Characteristics The causal agents in African trypanosomiasis are flagellate protozoans called trypanosomes. There are two main types, which are morphologically indistinguishable but which produce diseases with different characteristics. Both are named for Sir David Bruce, who was instrumental in defining the trypanosome groups. The first identified trypanosome, and the one responsible for the sleeping sickness or "Negro lethargy" described in eighteenth- and nineteenth-century sources, is *Trypanosoma brucei gambiense*. This variety was isolated between 1901 and 1903 and is prevalent in central and western Africa. The second type, which was de-

scribed and named in 1910, is *Trypanosoma brucei rhodesiense.* Its range is eastern Africa, including Zambia, Zimbabwe (Rhodesia), and Botswana. The vector for both trypanosomes is the tsetse fly (genus *Glossina*). The two major types of tsetse which communicate trypanosomiasis are *Glossina palpalis,* the primary vector for the Gambian trypanosome, and *Glossina morsitans,* which carries the Rhodesian variety. *G. palpalis* has a wide range, lives in brush near water, and feeds on the blood of reptiles, though humans are an acceptable substitute. *Glossina tuscipes* and *Glossina tachinoides,* which are found in eastern and central Africa and western Africa respectively, behave similarly and transmit *T. brucei gambiense. G. morsitans* is found in woodland savannahs and along watercourses in arid regions. They feed on game animals as well as humans. In addition to *G. morsitans, Glossina swynnertoni* and *Glossina pallidipes* transmit *T. brucei rhodesiense.* All are found in eastern Africa, though *G. morsitans* is in central Africa as well.

The primary reservoir for *T. brucei gambiense* is human beings, while wild animals act as reservoirs for Rhodesian trypanosomes. Wild animals are not susceptible to the Gambian trypanosome, but domestic animals are. Gambian trypanosomes are sensitive to arsenic compounds and can be treated, but the Rhodesian variety is resistant. Rhodesian trypanosomiasis is acute and often kills before the nervous system becomes involved. Gambian trypanosomiasis acts slowly, becomes chronic, and eventually involves the nervous system, producing the symptoms of sleeping sickness.

The transmission of African trypanosomiasis by the tsetse fly begins when the fly feeds on an infected host. The trypanosomes are ingested with blood and develop in the fly's lower gut. When the infected fly bites again, the trypanosomes are injected into the victim's skin with the fly's saliva. A mechanical transfer, where infective material is carried from a host to a susceptible victim without intermediate development in the fly, is possible, but it occurs very seldom. The most effective means of preventing infection is to break the infective chain by avoiding contact with flies and by excluding infected humans or animals from zones which are free of infection. Tsetse fly control by clearing undergrowth and direct attack with pesticides will give long-term protection.

Several environmental and cultural factors are important in the epidemiology of African trypanosomiasis. Drought will bring flies and people into proximity with one another around shrinking watercourses or pools. Conditions are then excellent for transmission, with a small tsetse population feeding nearly exclusively on humans. Wet conditions have an opposite effect, as tsetse spread outward from riverine centers and disperse over a wider area. Such dispersion reduces the possibility of human contact with infected flies. Apart from climatic factors, certain occupations maximize contact with flies and are dangerous. In areas where *G. palpalis* abounds and the infection threat is from the Gambian trypanosome, farmers who work rich valley soils with streams or rivers nearby are in constant danger. In woodland areas with *G. morsitans,* farmers who work on the edge of woods, or who clear brush for new fields, are in danger as are people who fish in dry river pools. Miners using canalized streams to wash dirt from ores are also exposed, as the periodic outbreaks of sleeping sickness in African mining regions show, and the same is true of road and railroad workers, especially bridge builders and timber cutters.

Clinical Symptoms The Gambian version of African trypanosomiasis develops very slowly. After initial exposure, 7 to 10 days pass before the first lesion appears in the area where the infection occurred. Swelling begins, with discoloration and a rash which finally sloughs off. This reaction is seen more often in Europeans than in Africans. Constitutional symptoms—chills and shivering or sweating—will appear within three weeks of the initial lesion, usually more swiftly in Europeans than in native Africans. The infected person suffers from headache, irritability, and insomnia, while swelling in the lymph nodes becomes generalized. Other conditions which may occur include male impotence, spontaneous abortion in females, tachycardia, and hypotension. Two months or more are required for the disease to enter the nervous system, and it is not uncommon for several years to elapse. Once the infection attacks the nerve centers, however, the prognosis becomes poor. The victim suffers from feverish

attacks increasing in number, the lymph nodes shrink and harden, and the characteristic personality changes develop. Behavior becomes unfocused, insomnia is chronic, there is emotional instability, and there are periods of mania or confusion. The face takes on a vacant expression which has been called "silent grief," the tongue and hands are subject to tremors, the gait becomes uncertain, the head nods, speech is slurred, and terrible headaches develop. The headaches can drive a sufferer to suicide if he or she has energy enough. More commonly, death follows a growing somnolence and physical wasting.

Rhodesian sleeping sickness is far swifter and more violent. Most often, there are no initial symptoms, and the disease begins with a high fever and a dull headache. The fever continues, sometimes intermittently, while lassitude sets in and spreads. Rapid wasting, anemia, swelling limbs, heart involvement, tremor, and headache follow. Advanced cases show slow mental responses, slurred speech, and a flat, fishy stare. Death may come in the first few weeks from acute toxemia, and without treatment, death within nine months is virtually certain. In general there is no help for domestic animals which become infected.

Trypanosomes in Africa African trypanosomiasis appears to have existed long before there was any historical record, but since the affected African cultures produced no written tradition, evidence about the disease had to wait for non-African chroniclers. The first literary reference to sleeping sickness occurs in a passage written by the Arab world traveler, historian, and geographer of the fourteenth century, Al-Qualqueshaudî, or Ibn Khaldun. In speaking of the Malli kingdom and its rulers, he noted that the second sultan, Mârî Jâza, was "overtaken by the sleeping sickness (illat annawm) . . . a disease which frequently befalls the inhabitants of those countries, and especially their chieftains." In this case, Ibn Khaldun reported that the sultan was so overcome by sleep that he could hardly be wakened, that he was in this condition and growing progressively worse for two years, and that he died in A.H. 775 (A.D. 1373–1374).

Nagana, or animal trypanosomiasis, is suspected of playing an important role in the history of eastern Africa. The Arabs were interested in African trade and colonies, and while the Bantu people drove them out of the interior, they established a strong position on the southeast coast from which they maintained control over important trade routes. It is thought that the Arabs failed to expand their position because they were unable to rely on horses for war or transport where tsetse flies were prevalent. During the fifteenth century, the Portuguese rounded the Cape of Good Hope and challenged Arab control over trade in the Indian Ocean and the Persian Gulf. The struggle spilled onto the east coast of Africa in the early sixteenth century. The Portuguese reported heavy losses in their camel and horse herds, and they accused the Arabs of poisoning the wells. It is fairly certain, however, that the Portuguese problem was trypanosomiasis communicated by tsetse flies and not their Arab enemies. The Arabs had faced the same problem earlier, and until the second half of the nineteenth century, when steamboats and railroads revolutionized African travel, there was no choice in eastern or central Africa but to walk. Neither draft nor pack animals could survive in the tsetse regions, and this inability to keep and use large work animals may have been one important reason for the failure of central Africa to develop beyond the village stage. Human trypanosomiasis did not reach eastern and central Africa until the second half of the nineteenth century, and human bearers were used for transporting goods.

In the years after Ibn Khaldun, there is no connected account of sleeping sickness until the eighteenth century, when John Atkins, an English naval surgeon, discussed the disease in his book *The Naval Surgeon* (1734). Atkins visited the Guinea coast in 1721, where he made the acquaintance of the "sleeping distemper." He found the condition to be prevalent among the natives, to appear more frequently among the young than among the old, and to be extremely dangerous. Those few who did not die, he reported, "lose the little reason they have and turn idiots." A similar account appeared in 1794, which added the information that not only was the "Negro lethargy" widespread but slave dealers had learned to identify enlarged glands that indicated exposure to it and would refuse to take any slave showing that

symptom. African slaves carried to the Americas who were captured in the interior often developed these symptoms on the voyage west or in the new slave quarters. Reports of the time which mention slaves wasting away from grief or homesickness may be describing people in the later stages of sleeping sickness. Slave masters whipped these unfortunates to arouse them or "take their minds from their troubles" and so hastened their inevitable deaths. The value of a slave dropped precipitously when sleeping sickness was suspected.

During the nineteenth century, both the European awareness of sleeping sickness and the incidence of the disease expanded. These developments were related. In 1840, Robert Clarke described what he called "narcotic dropsy" in Sierra Leone, commenting that the disease appeared to be more prevalent in the interior than it was on the coast. In 1876, a French naval surgeon named Coné produced an epidemiological survey for lower Senegal. He found sleeping sickness very widespread, leaving villages abandoned and empty or dilapidated and run-down. Reports from the Congo also described a spreading incidence of sleeping sickness. The disease was endemic as far up the river as Stanley's Pool, and increased trade on the river, especially after the introduction of steamboats in 1876, spread it more rapidly.

Henry Morton Stanley, the journalist and adventurer-explorer who "found" Dr. Livingstone, later became economic development chief for Belgium's King Leopold II. His undoubted success in developing the Congo as an avenue of commerce contributed directly to the rapid spread of sleeping sickness into central and eastern districts. Missionary reports cataloged the spread of the disease in terms of emptied villages and depleted missions. The natives brought their sick to the mission stations to be cured, thus infecting previously uninfected zones. Fatalities soared, people died by the hundreds, and the condition continued to spread. It was estimated that 500,000 people died of sleeping sickness in the Congo alone between 1895 and 1905. Even if this estimate is greatly exaggerated, which does not appear to be the case, it is apparent that the number of deaths in the area was appalling. European-sponsored commerce and industry vastly enlarged the active areas of human trypanosome infestation as infected persons traveled freely, while tsetse flies were carried on the new vehicles, especially the river boats. Sleeping sickness thereby attained a dangerously high incidence throughout sub-Saharan Africa.

Understanding African Trypanosomiasis Consciousness of the connection between nagana (that is, trypanosomiasis in animals) and the tsetse fly developed during the settlement of the Transvaal by Dutch colonists escaping British domination in the Cape colony in the early nineteenth century. These "Voortrekkers" moved into tsetse country in the 1830s and immediately suffered heavy cattle losses. they soon connected their losses with fly attacks, but they also noticed that the flies tended to remain in well-defined locations. It was possible to plan routes which avoided fly-infested zones. As their experience broadened, the Dutch colonists developed other practical measures for protection. They herded their cattle in fly-free zones; as they learned that flies were daytime feeders, they crossed infested regions at night; they found that goats seemed to be immune to nagana, so they planted goat herds in areas with fly infestations; and they recognized an association between wild game and flies, which led them to shoot out game colonies in tsetse-infested areas. Finally, they began to destroy tsetse habitats by cutting and burning brush along watercourses and by intensive agriculture. In the course of the nineteenth century, while sleeping sickness ran wild through central Africa, in South Africa and what is now Zimbabwe, Dutch and English settlers found ways to cope with fly infestation which made agriculture possible. The measures which they developed from observation and experience were ultimately confirmed to be epidemiologically sound, and some of their practices were used later in scientifically based campaigns.

The growth of scientific knowledge concerning sleeping sickness began in the early nineteenth century, but substantial progress did not come until the early twentieth. The German entomologist, zoologist, and physician Dr. Christian R. Wilhelm Wiedemann named the tsetse fly *Glossina longipalis* in 1830. At the time he did so, the fly was little known to European entomologists. R. G. Cummings, hunter, explorer, and African adventurer extraordinaire, accepted the name *tsetse* from the Tswana people and popularized it

in his book *Five Years of a Hunter's Life in the Far Interior of Africa* (1850). He speculated that the name reproduced the curious buzz of the fly's approach. Another English explorer and scientific curiosity seeker, Maj. Frank Vardan, investigated the effect of the tsetse's bite on horses. He sent specimens of the fly to a London entomologist, Dr. J. O. Westwood, who identified it as *G. morsitans*, and reported his findings to the London Zoological Society in 1850.

As the craze for African exploration and colonization mounted in the second half of the nineteenth century, the information on tsetse flies, nagana, and sleeping sickness multiplied. The famous medical missionary, Dr. David Livingstone, whose accounts of his 32 years of African explorations thrilled thousands of readers, described the fly whose "bite is certain death to the ox, horse, and dog." Livingstone imported camels and water buffalo in an attempt to find work animals to substitute for the susceptible species. Dr. Livingstone firmly believed that the tsetse fly carried a sort of poison which it communicated by its bite. He was also certain that game animals and human beings were immune. In his autobiography *Travels* (1857), Dr. Livingstone recorded how he exposed himself to biting flies, and the minor inflammation which followed. Modern authority takes this as further evidence that eastern Africa, where Livingstone was exploring, was free of sleeping sickness, though infested with nagana.

In 1894, Maj. (later Sir) David Bruce was ordered to Natal and Ubombo in what was then Zululand to carry out a scientific investigation of nagana. Bruce had just completed his successful work on Malta fever. During the period 1894–1895, Major Bruce found trypanosomes in the blood of cattle and proved that the tsetse fly was responsible for transmitting them. He showed that nagana and what was called tsetse fly disease were the same thing, and that the disease resulted from the transmission of a parasitic infection from infected animal reservoirs to healthy susceptible creatures. This disposed of the poison theory, and Bruce also proved that nearly all domestic animals, with the possible exception of goats, were susceptible. Finally, Bruce answered the question of where the infection lodged by identifying *T. brucei* in wild animals such as buffalo or antelope which remained perfectly healthy. Wild animals were "reservoir hosts" where uninfected tsetse flies acquired the infection which caused nagana when injected into susceptible domestic animals.

David Bruce revealed the basic facts concerning the transmission of animal trypanosomiasis, but this achievement, though of the first importance for agriculture and African economic development, left the increasingly pressing issue of sleeping sickness open. Human trypanosomiasis was spreading, thousands were dying, and there were high economic stakes as well. Africa was rich in natural products, there were vast areas for colonization, and commercial exploitation had just begun. In response, Belgium's King Leopold II subsidized an expedition from the Liverpool School of Tropical Medicine, while the British army, the colonial office, and the recently founded London School for Tropical Medicine embarked on a series of coordinated investigations.

A severe sleeping sickness epidemic in Uganda in 1901, which claimed more than 20,000 victims, spurred the demand for action. Sir Patrick Manson's First Sleeping Sickness Commission went out from the London School of Tropical Medicine to arrive in Mombasa in June 1902. This commission, whose senior member was 39-year-old Dr. Cuthbert Christy, included Dr. Carmichael Low and Count Aldo Castellani, a brilliant 25-year-old student in bacteriology at the London School. Castellani later became embroiled in a bitter controversy over priority in discovery with Sir David Bruce. This commission looked for the cause of sleeping sickness by studying the action of *Filaria pustans*, which was thought to play a role in elephantiasis. When the investigation failed, no alternative hypothesis emerged, and the commission broke up, though Castellani remained in Africa to pursue his research.

In the meantime, Robert Mitchell Forde, a hospital surgeon in Bathhurst, Gambia, in western Africa, and Dr. J. E. Dutton, who came to Africa from the Liverpool School of Tropical Medicine, isolated a trypanosome from the blood of an English shipmaster who was suffering with an episodic fever. It was Dutton who named it *T. gambiense*. In March 1903, Alexander Maxwell-Adams published a note suggesting that human trypanosomiasis took two forms, depending on where the infection was active. When the parasite circulated freely in the blood, a chronic, irregular feverish condition resulted; but when it estab-

lished itself in brain tissue, lethargy and loss of function, that is, sleeping sickness, developed. C. J. Baker, a colonial office physician in Uganda, also found trypanosomes in a fever patient and wondered if the tsetse fly was responsible. On the other hand, in 1902, the team of investigators from the Liverpool School of Tropical Medicine working in Senegambia found only 7 out of 1000 blood samples in which trypanosomes were present. They made no connection with sleeping sickness.

Castellani, working at Entebbe in Uganda, had identified a streptococcus in postmortem examination of sleeping sickness victims which he thought was the causal agent. He also found and identified trypanosomes in the cerebral fluid of 5 out of 15 moribund sleeping sickness patients. When David Bruce arrived at Entebbe at the head of the Second Sleeping Sickness Commission in 1903, Castellani reported this result. Bruce, on the basis of his work with nagana, seized on the trypanosome, and working together, the two men identified trypanosomes in the spinal fluid of 70 percent of the sleeping sickness cases. No trypanosomes appeared in healthy natives, or in natives with other diseases. Bruce gave Castellani credit for finding the trypanosomes, but it was Bruce who recognized their significance and established the research which led to the proof that trypanosomes were the causal agent in sleeping sickness.

The Bruce commission attacked the problem of controlling sleeping sickness with the hypothesis that, as in nagana, the tsetse fly was the vector. Tsetse flies were common on the shores and islands of Lake Victoria, where sleeping sickness was also common. Case-incidence maps for the Kiva region were made, and missionaries were enlisted to organize fly-trapping teams among the villagers. There was an enthusiastic response. Four hundred sixty fly collections were made and mapped; the fly- and disease-incidence maps were compared and found to coincide. Experiments were organized in which flies that had fed on sleeping sickness patients were permitted to bite monkeys. The monkeys were subsequently found to have trypanosomes in their blood. No other fly, insect, or animal was found that performed the vector function.

Sleeping sickness was eradicated from the Lake Victoria vicinity by withdrawing the people from the areas where tsetse flies prevailed. Sick humans were acting as a reservoir. Two years later, when sleeping sickness appeared on the east shore of the lake where it had not been before, the trypanosome reservoirs were found in healthy wild game. The vectoring mechanisms were the same. Subsequently, additional trypanosomes were found, beginning with *T. brucei rhodesiense*, and today there are seven different varieties associated with tsetse flies, and two more which cause American trypanosomiasis. Several insects have been found to act as vectors in the American version.

Modern Treatment and Control Early experience with sleeping sickness led to the use of arsenic compounds, which were effective if applied in the first stages of the disease. Dr. Albert Schweitzer, who went to Lambaréné and established his hospital there in 1913, and Dr. Eugene Jamot, a French army physician who was posted to Chad in 1911 and went to Brazzaville in the Congo to fight sleeping sickness in 1916, epitomize the struggle. Dr. Schweitzer operated from his hospital center, to which the victims were brought. Dr. Jamot went in search of his cases. Both men relied on chemotherapy based on arsenic. The specifics were first atoxyl and later tryparsamide, which were used to kill the trypanosomes in the bloodstream. The treatment was successful against *T. brucei gambiense*. Modern treatment has expanded the chemical base, using suramine or pentamidine where there is no nervous system involvement and such powerful and highly toxic compounds as melasoprol in advanced cases. The first principle of successful treatment is to begin as early as possible. Modern chemotherapy has materially reduced the mortality rate for sleeping sickness, but cases in their late stages are still highly dangerous and offer a poor prognosis.

Control measures against African trypanosomiasis aim at controlling tsetse flies, eliminating disease reservoirs, and preventing contact with the flies. Intensive agriculture and game destruction has been effective, while direct attacks on the flies with insecticides (most recently DDT), extensive trapping programs, and the introduction of biological enemies have all been used successfully. Before World War II, these campaigns were administered by European colonial offices. As the