

KYLE (D.B.)

THE
PATHOLOGY AND TREATMENT
OF
TETANUS:

Including a Series of Investigations in regard to the
Micro-Organism of the Disease and the Influence
of Disinfectant Substances on the same.

A STUDY FROM THE PATHOLOGICAL LABORATORY OF THE
JEFFERSON MEDICAL COLLEGE.

BY

D. BRADEN KYLE, M.D.,

Assistant Demonstrator of Pathology in the Jefferson Medical College.

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Compliments of
the author



Bacillus of Tetanus. Beck $\frac{1}{2}$; homogeneous immersion, camera lucida. Drawn by Dr. Bevan.

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TETANUS is an acute infectious disease which follows traumatism, and is due to a special micro-organism, the *bacillus tetani*. The disease is characterized by persistent rigidity of the muscles of the jaw (trismus), and frequently of the greater part of the voluntary muscular system, with paroxysms of tonic spasms, irregular temperature and pulse, the intelligence being preserved.

The disease has been classed as traumatic and idiopathic. From the present knowledge of the origin of the disease, possibly a better classification would be traumatic and simulated, as it is generally conceded that there

* My thanks are due to Dr. Coplin for the directions given me in this research.



must be some traumatism, no matter how trivial or how produced. Under the simulated class would be placed all cases now known as nervous, emotional, or psychical ; in fact, all cases which do not follow traumatism.

As to the duration of tetanus, it is classed as acute and chronic. The acute lasting from a few minutes to several days ; the chronic lasting from eight days to seven weeks ; in which case a more favorable prognosis may be given.

As far as the writer is aware, no case of traumatic tetanus, accompanied by bacteriological research, has been reported in this country. Senn has reported the production of tetanus in an animal from a case of chronic tetanus, but does not state that any attempt at isolation of the bacillus was made.

Several investigators on the continent (Nicolaiev, Rosenbach, Flugge, Bonomi, Beumer, Eiselsberg, Giordano, Ohlmüller, Kitasato, Belfanti, Pescarolo, and others) have made more or less complete studies of cases, but the present status of the bacillus of Nicolaiev has been reached by the combined work of at least one dozen investigators.

In this country no reports other than the one cited have been published. The writer is aware that a most complete investigation was made at the Johns Hopkins Hospital by Welch, Abbott, and others, as to the exogenous origin of the disease, but there has been no published report. The report of Professor Park, of Buffalo, which he read at the College of Physicians in Philadelphia, showed the bacillus of tetanus, with which he was

able to produce the disease in animals, but did not state that a pure culture was again obtained from the animal.

The attempts made at isolation and pure cultivation have been almost entirely futile, and the inoculation experiments made have been with impure cultures, contaminated with cocci and a smaller bacillus ; a greater number of the experiments were made by inoculations from different kinds of earth and a very few were made from traumatic cases.

In the laboratory reports made by Park, of Buffalo, and Charcot and Belfanti, of Paris, they claimed to have procured pure cultures of the bacillus of tetanus.

In August, of last year, the writer began these investigations, and at that time our knowledge of the disease was fragmentary, made up of the combined investigations of Continental observers, to be referred to later on. These observations were, many of them, contradictory and confusing, and the scientific world recognized the chaotic condition of the study of this most fatal disease. Although the date of the investigations made by Belfanti and Pescarolo in Charcot's laboratory is not given, it is to be assumed that they began much earlier than the writer, but his work had been nearly completed at the time of their published report, in December. The writer has attempted to make clear points not hitherto understood, and, long before the reports above referred to, had arrived at conclusions essentially the same, on many points at wide variance with pre-existing knowledge on the subject. Had he known that others were also reaching con-

clusions which he had reached, and invariably arrived at the same result,—viz., that the bacillus was not an obligate anærobe,—many repeated experiments could have been avoided and further research added.

Tetanus is by no means a new disease ; it is described by Hippocrates and Galen. In 1859, Betoli related the case of a bull that died of tetanus after castration. Several slaves ate of the flesh of the dead animal, and of these, three were affected with tetanus, two of whom died. In 1870, Anger reported a case of spontaneous tetanus in a horse, after which three puppies, in the same stable, were also affected. Kelly, in 1873, had three cases in the same week, all arising in a civil hospital, and a few days later there was a fourth case in a neighboring hospital. Larger, in 1853, reports a case in which the patient received a slight injury while working in a barn-yard, and in four weeks developed tetanus ; on investigation, it was found that a horse affected with the disease had been in the stable opening into the yard in which the accident occurred. The same writer reports five cases in one village in eighteen months and under different climatic conditions.

Senn, who refers to Bonomi's observations, states that out of seventy persons injured by the falling of a church tower during an earthquake, seven were attacked by tetanus. Gower reports two cases following alcoholic intoxication ; at least, there was no other assignable cause. As to puerperal tetanus, which occurs chiefly in tropical climates, it is supposed to be due, in at least a majority of cases, to retained placenta. The same writer

reports that in Bombay, in three years, two hundred and thirty-two women died of the disease.

As to the time of incubation, it may last for varying periods after the infliction of a wound. The case reported by Dr. Robinson, where the patient cut or rather scratched his finger with a broken piece of porcelain, died of tetanus in fifteen minutes; although this occurred in a hot climate, and is reported as a case of tetanus, the diagnosis is to be questioned. Larrey, who had great experience with the disease during Napoleon's campaigns in Egypt, found that it occurred from the fifth to the fifteenth day. The reports of surgeons during the Peninsula war showed that the disease manifested itself after the twenty-second day; it may occur as late as one month, as in the case reported by Sir G. B. Lane. The wound may have undergone complete cicatrization before any symptoms appear.

Even racial peculiarity seems to effect the disease, as the dark-skinned are more likely to take it than the white, even when exposed to the same climatic influences. In traumatic tetanus the proportion between the sexes is six male to one female. The order of frequency with which the several parts have been the seat of the wound that caused tetanus is (1) hand; (2) leg; (3) foot; (4) head and neck; (5) arm; (6) trunk (Gowers). The disease is most common in Northern Italy, its maximum being in Lombardy. Hospital reports show a mortality of fifty per cent.; in private practice it is somewhat higher.

Stewart, of England, reports a case of tetanus in an infant fourteen days old. The cord was ligated in the usual way. On the fifth day the cord dropped off, and nine days after tetanus developed, and in five days more the child died. When tetanus developed the cord was perfectly healed (*British Medical Journal*, February 21, 1891, p. 405).

Cold climate and altitude is detrimental to the development of the disease, while a tropical climate tends to enhance its development. During the campaign of Caucasus, the weather being persistently cold, Pirogoff saw hardly any cases among the Russian wounded; while after battles during the warmer weather the mortality from tetanus had been great.

Of three hundred and sixty-three cases reported during the late civil war, three hundred and thirty-six died.

The disease sometimes seems to occur in epidemics; thus, in 1782, one out of every six infants born in the Rotunda at Dublin died within the fortnight after birth from the disease.

In St. Mark's Hospital, 1858, there were five cases of tetanus following operations for hemorrhoids.

Prior to 1884 various hypotheses were set forth as to the cause of tetanus. It was said to be a disease consisting essentially in an excited state of the spinal cord and of the medulla oblongata, in fact, of the whole spinal system, giving rise to painful and continued spasms of the voluntary muscles and the diaphragm, following a peripheral nerve irritation, causing an ascending neuritis (Erich-

sen). It was claimed by the same writer to be due to the irritation of the nervous system, from the presence of worms in the intestinal canal, and also by uterine irritation ; it seems sometimes attributable to exposure or cold, and in this apparent causation it is called by some writers *tetanus a frigore*. It has been conjectured that the disease is sometimes a manifestation of rheumatism. Billroth states that "all symptoms indicate an irritation of the spinal cord," or of the portio-minor of the fifth pair.

In 1875, Professor Wm. S. Forbes, in a paper read before the College of Physicians of Philadelphia, in which he reported a case of traumatic tetanus, in speaking of the cause, stated it to be his belief "that it is a self-generated agent, akin to rabies and strychnine, exciting the nerve peripheries, which, by reflex action cause the augmented disintegration of muscular tissue, the product of disintegration further exciting the nerve peripheries until there is established the condition known as tetanus.

Rokitansky claimed to have seen the development of young connective tissue in the spinal medulla, which would make it appear that there was an inflammatory affection of this nerve-centre. Goll, of Zurich, and Meynert, of Vienna, confirm this, but as to its cause there was a difference of opinion. Some writers do not believe that the nervous system is primarily affected, but think that the blood first becomes diseased and acts secondarily on the nervous system.

The morbid anatomy of the disease revealed nothing but what has been found in

other diseases. Rose claimed that tetanus and hydrophobia were both primary blood-diseases, and it is a well-known fact that the two diseases are very much alike. It has been stated by some experimenters that by inoculating animals with the blood or secretions from a case of tetanus, hydrophobia was induced. Leyden produced tetanus in a dog by passing a strong current of electricity through the whole spinal medulla; the symptoms were accompanied by marked elevation of temperature. Frick claimed that a surplus of heat was formed in the muscles and thence distributed to the blood. Some writers (Erichsen and others) believed that depressing emotion predisposes to the disease; this form might be properly called psychical tetanus.

Theorizing as to how particular varieties of injuries to nerves produce tetanus is useless. It is rare that a simple division of the nerve produces the disease, but crushing and partial division have been attributed as frequent causes. The disease has followed simple wounds of the skin, and arisen from granulating surfaces, even after cicatrization; a blister, or the sting of an insect may produce it. All kinds of wounds cause it; such as incised, punctured, contused, lacerated, and surgical-operation wounds, as well as burns. In rare instances it has followed injuries which involved no breach of surface, as flogging or a fall on the back and spine. It has long been known that troops are peculiarly susceptible to it; also persons injured by fire-arms and toy pistols; persons engaged in taking care of horses are frequently affected,

hence the "equine origin;" horse-dung seems especially open to suspicion, and it is found that ordinary dust, garden-earth, and surface-soil play an important part in the causation of tetanus. That tetanus is especially apt to occur in the feeble and debilitated has also been noted; hence any condition that lowers the tone of the nervous system is likely to cause the disease.

It is most likely to follow injuries of the extremities; in the present light of investigation this is to be explained on the ground that these injuries are more likely to be infective. A tropical climate seems to favor the disease, and altitude seems to lessen the liability to its development. It may occur at any age; the young, the middle-aged, and the old alike suffer, yet all cases follow traumatism, even the "tetanus neonatorum," which may follow the ligation of the umbilical cord. Although the disease was known to be infectious, it was only in 1884 that the microbial cause was discovered, almost simultaneously by Nicolaiev and Rosenbach. Nicolaiev showed the exogenous origin of the disease by finding the bacillus of tetanus in earth. Rosenbach found a similar bacillus in the pus from a case of traumatic tetanus. The identity of the bacillus of tetanus with Nicolaiev's bacillus of earth tetanus was demonstrated in Koch's laboratory, April 10, 1887. The discovery made by Nicolaiev and Rosenbach has been confirmed by many noted bacteriologists, such as Koch, Carle, Ratione, Beumer, Giordano, Ferrari, Hacksinger, Shakespeare, Bonomi, Brigger, Kitasato, Park, Abbott, Welch, and many others.

The ptomaines of tetanus have been isolated, but the writer was unable to make any investigation on this subject. The four ptomaines isolated are (1) tetanine; (2) tetanotoxine; (3) not named; (4) spasmotoxine. It is generally conceded that the cause of death in the disease is due not to the bacillus, but its products,—the ptomaines.

The history of the case which I studied, which extends over a period of thirty-five days, is as follows :

M. J. McL., male, aged 20, residing in Philadelphia, is by occupation a stone-cutter. On August 5, while at work, he stepped on a board containing three sharp-pointed scaffolding nails, the nails being driven through the board so that they pointed together; the sole of his shoe being thin, the nails penetrated into the foot, inflicting a punctured wound three-quarters of an inch in depth, extending obliquely inward at a point one inch behind the last metatarso-phalangeal articulation; the injury caused him so much pain that he was obliged to quit work immediately. He applied at a drug-store for something with which to relieve his pain, and was given a bottle containing equal parts of *tinctura opii* and *liquor plumbi subacetatis dilutus*. The wound was not opened, and nothing was done to cleanse it or in any way to render it antiseptic. The solution was applied to the injured part by means of cotton and lint.

At 8 P.M. the wound was very painful, slightly swollen, with great discoloration of surrounding parts. A poultice of bread and

milk was applied, being placed over the lint and cotton ; this was left on until 8 A.M., when the poultice and lint were removed, and a few drops of bloody serum and pus showed on the cotton which was next to the wound. The patient had passed a quiet night. The wound was then washed in water in which wood ashes had been soaked for three hours ; this was on the morning of August 6 ; after washing the wound in this solution a large piece of fat bacon was applied. This treatment was continued until August 9, the patient suffering very little pain. The wound closed on the third day ; no discharge on the dressings, except the first two, and then only a few drops of pus and blood. The foot was slightly swollen, but at no time very painful. On Saturday, August 9, the fat pork was followed by flaxseed-poultices, and this treatment continued until August 16, when all treatment was stopped. The wound was never washed out, and remained closed after the third day. On the 13th the swelling entirely left the foot, but on the next day, when dressing it, the patient noticed some discoloration on top of the foot, extending out to the toes ; this had all disappeared by the 16th.

On Friday, August 15, he felt a stinging sensation, seeming to originate in the temporo-maxillary articulation. On moving the jaw slight rigidity was found to exist ; also slight rigidity of the muscles of the neck. These symptoms continued until Monday, the patient saying nothing as to his condition at the time.

On Monday, August 18, the patient re-

sumed work, but on account of increased rigidity of muscles and general indisposition he was unable to work longer than 12 M., when, on attempting to eat his dinner, his jaws were more rigid, deglutition difficult; he suffered from pain in his back, occipital headache, weakness in the lower extremities, and slight muscular inco-ordination.

During the afternoon he called at Dr. Smith's office; this was the first medical advice sought. After examining the patient Dr. Smith pronounced it a case of tetanus, and gave him a plaster for his back and prescribed for him; what was prescribed the writer was unable to learn. Two doses of the medicine were administered, and that evening, August 18, the patient sought medical advice at Dr. J. W. Hearn's office. Dr. Hearn being out of the city, he was examined by Dr. Coplin.

On examination the condition of the patient was found as follows:

Temperature 99° F., pulse 90, muscles of the jaw rigid, the patient not being able to open them more than one-half inch; there was inability to protrude the tongue, rigidity of the muscles of the neck, flushed face, and quick, jerky articulation; on tapping the muscles of the face great pain was produced; he also complained that the jostling and jolting of the car increased his pain; the expression of his face showed mental anxiety; his bowels were constipated. The patient could not take solid pabulum, but could imbibe fluids, showing marked difficulty of deglutition. He complained of temporo-frontal headache. From the symptoms given and history, the case

was diagnosed one of traumatic tetanus ; he was ordered a saline purgative and a mixture containing bromide of sodium, 1 drachm to each dose, to be given every two hours, and the importance of feeding the patient at intervals of every two hours was urged upon the parents, the diet to consist of liquids, especially milk, to be administered frequently, so that not less than thirty-two ounces of milk be given in twenty-four hours ; also broths and beef-tea to the same amount. He was ordered to bed in a dark room, and to be kept absolutely quiet.

On August 19, at 2 P.M., Dr. Coplin paid the first visit to the house. The patient had then taken one ounce of the bromide of sodium ; the trismus was still marked ; the rigidity of the muscles of the neck was increased, with marked arching forward of the lumbar region (opisthotonos). He complained of twitching and jerking of the muscles in the injured limb, affecting more particularly the calf muscles and gluteal muscles. The opisthotonos was more marked during the pains, the facial expression distorted (risus sardonius), lips cyanotic, finger-nails blue, respiratory movements quickened, and short clonic and tonic spasms were induced by any movements which involved the muscles of the neck, back, or inferior extremities ; also by attempts at laughter,—less marked by talking ; mental condition showed no change, except he was lapsing into a condition of indifference as to the termination of his case. The foot was carefully inspected, and no evidence of inflammatory process, either upon dorsum or plantar surface, could be observed ; except

at the point where the nail had entered, it would have been impossible to have told which foot was the seat of the disease ; cicatrization was complete. At the point of the wound there was a small indurated area, about one-half inch long and one-quarter of an inch wide, somewhat tender, which produced convulsive movements of the limb and increased the opisthotonos when pressed upon. It was not surrounded by an area of redness, and showed no evidence of an inflammatory process other than that offered by the tenderness.

The advisability of opening the wound was discussed at the time, but the full consent of the patient and family could not be obtained. Treatment was ordered continued, and on account of the large number of friends who had visited the patient, the family were again made fully aware of the necessity of absolute quiet ; the patient was ordered to a larger room, put in a large, roomy bed, and the feather-bed was removed.

On the 20th the trismus was marked, and general tetanic condition was certainly unimproved, if not more marked. The necessity for opening the wound was urged upon the family, and conditional consent was obtained, providing he was no better on the following day. The patient's sleep had been interrupted, restless, irregular, rather a condition of somnolence than sleep, from which he was aroused by the slightest noise ; even the striking of a parlor match in the room annoyed him ; symptoms of mental aberration began to evince themselves ; while apparently perfectly conscious he made remarks which

had no connection with his surroundings ; he was laboring under the impression that he was not at home, and expressed a desire continually to be taken home.

On the 20th the patient had a slight nasal hemorrhage, the blood being collected on a linen handkerchief, and kept for inspection. (See laboratory notes.) The amount of urine passed was about forty ounces per day, and it was dark colored. (For report see laboratory notes.) He recognized all his friends and acquaintances who were permitted to see him, but inquired for no one.

On the evening of the 20th, Dr. Coplin called on Professor Bartholow, and gave him a brief outline of the case and details of treatment, which met with his full approbation, except that he urged the necessity for opening the wound.

On the 21st the trismus was improved ; the tongue could be slightly projected ; it was coated with a brownish, furry coat ; the surface was fissured longitudinally, and slightly swollen ; the secretion of saliva was apparently diminished, although respiration was carried on through the nostrils ; the lips and whole mucous surface of the mouth were dry and parched ; the lips were slightly blue ; the patient was indifferent as to his condition, and seemed to have lost all interest in the ultimate result of his case ; he had hallucinations, imagining work was going on in his room,—working at his occupation ; although he recognized all his friends and answered all questions rationally, the general tetanic condition was worse and tonic contraction of the muscles was most marked ; when the nurse

laid one of the patient's feet across the other he could not move it on account of extreme rigidity of the muscles.

The consent of the family having been obtained, it was decided to open the wound. The foot was thoroughly antiseptized, first scrubbed with soap and water, and then with a solution, as follows :

℞ Hydrarg. chlor. corros., ℥i;
Ammonii chloridi, ℥i;
Alcohol, q.s. ad f℥i.

Sig.—One drachm of this solution to one pint of water.

The instruments were rendered thoroughly aseptic by means of heat and carbolic solution. An incision one inch in length was made through the seat of induration. From the wound blood was drawn by means of vacuum-tubes, assisted by a fillet around the limb to prevent the venous return ; about two ounces of blood were withdrawn from the wound. In the bottom of the wound was a sinus, which contained sero-sanguineous fluid, but no pus ; in the blood that escaped, minute particles of rust and other foreign substances were found, both macroscopically and microscopically. The blood was all collected in tubes for examination. (See laboratory notes.) The wound was then washed out with an aseptic solution, as first used ; after thoroughly washing and drying the wound, it was mopped out with pure bromine and packed with iodoform gauze ; a dressing of bichloride gauze was applied with a turn of the roller. The bromides were increased to 45 grains of the sodium salt and 15 grains of the ammonium salt every two hours. At

9 P.M. the patient was resting easier, was evidently affected by the bromides, and upon rousing him to take his medicine would immediately be attacked with paroxysms of pain, the muscles become rigid, and he would assume the position of opisthotonos ; at times he would lapse into a restless sleep, or rather somnolence, from which he would be disturbed by pain, the body assuming the characteristic position and the face being distorted. He was aroused every two hours, and the medicine given regularly.

*Friday, August 22, at 9 A.M., on rousing the patient, exacerbations of spasms took place, during which the muscles became very hard ; these paroxysms lasted from one-quarter to one-half minute, and were accompanied by excruciating pain in the suboccipital and lumbar region ; the tetanic symptoms were more marked than on the previous day ; the trismus remained the same, the jaws being in a semiclosed condition, which condition they had been in from the beginning of the disease, as the patient, finding his jaws gradually becoming set, pushed between them some of the bedclothes, thus preventing their entire closure ; the angles of the mouth were slightly drawn upward and backward, giving him the peculiar expression called *risus sardonius*.*

At nine in the evening, the thermometer marked an increase of two degrees, the other symptoms continuing about the same, except the tetanic wave, which was increased ; each paroxysm showed increasing intensity, the patient assuming the positions of opisthotonos, emprosthotonos, and pleurothotonos,

alternating from one to the other during the spasm. The patient, since the morning of the 19th, had taken one drachm of bromides every two hours, making one and one-half ounces in the twenty-four hours, and in all, up to the morning of the 22d, four and one-half ounces. The symptoms were increased in intensity from six o'clock until eleven in the evening ; the paroxysms could be excited by mental emotion and by peripheral impressions. During the paroxysm the tetanic fixation of the respiratory muscles threatened a fatal termination by asphyxia ; this condition led to the most marked irregularity of the cardiac movements, both in number and in rhythm ; attempt was made to use the sphygmograph and cardiograph, but the jerking tendons, and rapid alternation between posterior and lateral arching of the trunk, precluded their use either at the wrist in the one case, or at the apex in the other. The bowels being constipated, an enema of hot water was ordered ; this failing, it was repeated in the morning ; the stool consisted of hard masses of fæcal matter. The patient was ordered, in connection with the bromides, 15 grains of chloral, to be taken every two hours, making in all three drachms of chloral and twelve drachms of bromides in twenty-four hours. The patient's intellect was unaffected.

August 23.—Same treatment continued ; the trismus was still well marked ; the other symptoms were increased ; the spasm often commenced in the injured limb. This fact is of much interest, as many writers, of which Gower is the most prominent, assert that the

spasm rarely, if ever, begins in the injured limb. It is also stated by some writers (Flint and others) that the paroxysms occur more during the day; if there was any difference in this case, they were more frequent at night. During the intervals between paroxysms the patient assumed the characteristic position of the disease; his condition was that of stupor or somnolence rather than natural sleep; occasionally he would lapse into a sleep from which he would be aroused by paroxysms of pain.

The nourishment taken by the patient consisted of thirty-two ounces of milk and twenty-four ounces of the beef-tea in twenty-four hours. The temperature showed the usual morning remission and evening exacerbation. The paroxysms, although brief, were repeated frequently,—every ten to twenty minutes, lasting from a few seconds (five) to one-quarter of a minute; the clonic paroxysm was accompanied by tonic spasm, affecting different groups of muscles; the patella tendon reflexes were exaggerated; the ankle clonus could not be tested satisfactorily, but we failed to elicit it at any time.

August 24.—The patient showed no change in symptoms from the previous day, but the effects of the combined use of the bromides and chloral were manifesting themselves; the medicine seemed to hold the spasm in abeyance for a time after administering, but as the effects of the medicine gradually passed off, the spasms recurred, seemingly in increased proportion to the length of the time they had been held in abeyance, the longer the period of rest the more intense the suc-

ceeding tetanic paroxysm. The wound was dressed with antiseptic gauze and the nurse ordered to keep the dressings damp with a bichloride solution (strength 1 to 1000). The amount of nourishment was increased to six ounces of liquid diet every two hours, and the necessity of nourishing the patient was urged. The nurse was also directed to administer the medicine and aliment regularly,—every two hours,—unless the patient was asleep, in which case the interval was not to exceed four hours. Treatment was continued as before ; the patient's bowels still being constipated, he was ordered one ounce of the *liquor magnesiæ citratis* of the shops, to be repeated every two hours ; this was also supplemented by a soapsuds enema night and morning ; the constipation was obstinate, but was overcome on the following morning.

The tonic rigidity of the abdominal muscles was most marked ; by palpation the feeling was that of passing the hand over marble. During the paroxysms of pain, the muscles of respiration being interfered with, the respiratory movements were limited in depth and increased in number ; the respirations increasing to as high as thirty-two per minute, their character jerky, irregular, and shallow ; during the paroxysms of pain the body was bathed in perspiration. It is a matter of interest to note at this point the remarkable connection between the spastic conditions and increased sudorific activity. Post-mortem sweating has been noted in cases of well-marked and rapidly-developed rigor mortis, and explained on the hypothesis that

the contraction has squeezed out the already secreted fluid in the gland. This same hypothesis is here applicable and well taken, as it seems hardly possible that in fifteen to thirty seconds the large drops of perspiration could have been secreted. The urine was scanty and highly colored, with specific gravity 1024, due to the exaggerated cutaneous activity.

August 25.—No change in the symptoms from the day previous, except a decline in temperature of one degree; the patient manifested no concern as to his condition and took no interest in his surroundings, but on being aroused, answered all questions intelligently. During the tetanic spasm the pupils always showed pin-point contraction, resuming the normal condition during the intermission. On the evening of the 25th slight symptoms of bromism were manifested; the patient's sensation was slightly impaired, and there was fetid, bromine breath, with cold extremities. The food consisted of thirty-two ounces of milk, animal broths thirty-two ounces, and two soft-boiled eggs during twenty-four hours.

August 26.—The symptoms of bromism were more marked; the trismus was much diminished, while the tetanic symptoms showed no diminution, except, while held in abeyance by the combined action of the bromides and chloral. On examining the patient the peculiar acne of bromism showed plainly on his face, shoulders, and upper extremities. There was marked pallor, and the heart was quick but strong, and there was a general subjective sense of coldness, the muscular move-

ments being tremulous and uncertain. The patient was unable to put his hand to his mouth or to cross his leg ; there was, in fact, well-marked muscular inco-ordination.

The altered character of the voluntary muscular movements presented so many points of interest as to merit the closest study. The modified motor and sensory conditions were due, of course, to the presence of the two conflicting elements,—viz., the tetanus and bromism ; these producing subjective and objective phenomena complex and not constant in any two consecutive observations. This may be illustrated by the fact that the patient could not put his hand twice in the same place ; if a hand was held out to him for hand-shaking, he would see it, recognize what the object was, and make futile attempts to grasp it, rarely succeeding ; his grasp when obtained was firm, even exaggerated, and he was little conscious of the force which he exerted, many times causing pain in the hand grasped, so firm was his grip. There was no loss of muscular power. Lying in his bed he could not cross his legs, although he was able to move them, even when attempts to restrain such movements were made. There was marked perversion of the so-called muscular sense. As already noted above, he was little cognizant of the force used in hand-shaking ; in conveying a glass to his mouth, he was likely to bring it abruptly against his face at almost any point ; his feet would press firmly against anything without his being conscious of the resistance. With this condition there was perversion of cutaneous sensibility ; heat and cold could be dif-

ferentiated unless intense,—*e.g.*, ice could be told from water at 130° F., but between 45° F. and 110° F. he could recognize no difference upon prolonged contact. The æsthesiometer elicited some very interesting facts ; one point could be recognized, but he could neither tell where he was being touched nor could he put his hand on the painful point ; he could only recognize two points when they were forcibly applied and under the most favorable conditions, at least four inches apart, if on the lower extremities, and but slightly, if any better, upon the upper ; the anæsthesia was well marked over the abdomen and the muscles of mastication ; two points could not be detected if applied to one finger, but if applied to two fingers, he could not tell which finger. After a few experiments the sensation became so perverted that he would declare you were touching him when no one was near him ; this could only be disproved by his seeing. The sensation conveyed to the sensorium through the sense of sight and hearing were never perverted, and only at brief intervals did he show the least tendency to temporary mental aberration, and this only when in the broken, restless, soporific condition, which we might term sleep. His mental condition was one of hallucinations and delusions, he imagining work was being carried on in his room ; sometimes his ideas were based on false objects, and then again based on a true object with a false idea, but at all times could he be reasoned out of his belief, and never was his condition one of insane hallucination or insane delusion. He would often talk in a rambling manner and often

indulged in meaningless and uncontrollable laughter. The mucous membrane of the mouth showed the same perversion of sensibility as already noted of the skin ; taste was perverted ; everything tasted sour ; coffee could not be sufficiently sweetened, and even the bromide mixture, made with syrup, had a taste of acidity. The patient's temperature had now declined to normal, 98.6° F. The nourishment taken was diminished from the day previous, consisting wholly of liquids, to the amount of twenty-four ounces in twenty-four hours, being allowed all the water he wanted to drink.

August 27.—The symptoms of bromism more marked ; the temperature declined to subnormal,— 98.5° F. ; the trismus much diminished, the tetanic spasms occurring at greater intervals and with less severity. In the evening the bromides were stopped ; the patient up to this time having taken thirteen and one-half ounces of the bromide and one ounce and seven drachms of chloral in eight days ; the patient was ordered to continue the chloral in 15-grain doses every two hours for three doses, beginning at 9 A.M. ; no more to be taken unless symptoms demanded.

August 28.—Patient rested well during the night, the paroxysms of spasms being less frequent and lighter. The tonic rigidity of the muscles of the neck and jaw showed lessening in degree, while the abdominal muscles were in a state of marked tonic rigidity ; the patient's bowels were kept open by means of enemata and magnesium sulphate in drachm doses ; nourishment consisted of forty ounces of milk and sixteen ounces of chicken-

broth; chloral administered at 1, 3, 5, and 7 P.M.

August 29.—Temperature had risen to one-half a degree above normal; slight diminution in all the tetanic symptoms, except marked rigidity of abdominal muscles; chloral administered at 8.30 and 10.30 P.M.; the nourishment same as the day previous.

August 30.—Chloral at 1, 3, 8, and 10 A.M.; trismus less marked, patient being able to open his mouth and partly protrude the tongue, but the muscles of the jaw were still stiff, as well as the muscles of the neck.

August 31.—The symptoms continued the same, the tetanic spasm being slightly more marked but at longer intervals. Chloral was given at 4, 6, and 8 A.M. and 7, 9, and 11 P.M.; the circulation showed no signs of weakening. The medicine was now changed, and he was ordered the following prescription:

℞ Chloralis,
Sodii bromidi, aa gr. xv;
Extract. hyoscyami,
Extract. cannabis indicæ, aa gr. ⅙.

Sig.—To be taken every two hours as indicated.

The amount of chloral taken up to this time was two ounces, three drachms, and forty-five grains.

September 1.—The tonic rigidity of the abdominal muscles was still marked, the patient resting well during the night, with occasional paroxysms of spasm; these paroxysms never occurred during sleep. Pulse was regular, although always increased in frequency during the spasm, which was probably due to a general vaso-motor spasm, due to ex-

cessive muscular contraction. The temperature in the morning was normal, with an evening rise of one degree. Patient's nourishment for the day consisted of thirty ounces of milk and eighteen ounces of broth. The medicine was given at 8 and 10 A.M. and 4.30, 8.30, and 10.30 P.M., and the patient was also ordered one-half ounce of beef peptonoids, to be given four times a day regularly.

September 2 to 8.—Symptoms continued about the same, the tetanic symptoms gradually becoming lighter and less frequent; the incision at point of wound had entirely healed. Some stiffness of the muscles of the jaw and extremities was noticed, more especially the extensors. The patient had now fully recovered from the effects of the bromide. The medicine was administered on September 3 at 9 and 11 A.M. and 1 and 3 P.M.; on September 4, at 11 A.M. and 3, 5, 7, and 9 P.M.; on September 5, at 2, 5, and 8 P.M.; on September 6, at 11 A.M. and 6 and 9 P.M.; on September 7, at 10 A.M. and 4 and 9 P.M. The bowels during this time were constantly constipated unless relieved by purgatives or enemata.

September 8.—The patient was able to take solid food for the first time, the muscles of his jaw being considerably relaxed; he was able to use the muscles of mastication, although they were somewhat limited in their action, and he still complained of dull aching pains in his extremities, especially in the injured limb. The medicine was used at 4, 8, and 11 P.M.

September 9, 10, 11, and 12.—Symptoms continued the same, the tonic rigidity of the muscles gradually lessening in inverse order

from their appearance, disappearing first in the parts affected last.

On the evening of the 12th the patient complained of severe pains shooting all through his body; the abdominal muscles were still very rigid, and temperature slightly elevated (100° F.). There was slight increase in the tetanic symptoms. The medicine was administered September 9 at 4 and 6 P.M.; September 10, at 5, 8, and 11 P.M.; September 11, at 9 A.M., 1 and 5 P.M.; September 12, at 10 A.M., and 2, 4, 6, 8, and 10 P.M. Food, consisting of milk, toast, soft-boiled eggs, and coffee, in fact, any easily-digested food, was given. The patient complained of great pain on moving.

On morning of September 13 the patient complained of pain on top (dorsum) of foot, at a point opposite the original wound. Upon examination, all the local signs of an abscess were present,—pain, swelling, heat, discoloration. The medicine was administered on 13th at 5 and 7 A.M. and 9 and 11 P.M. The foot was dressed antiseptically, and on the following day, the 14th of September, upon examination by Dr. Coplin, it was decided to open the abscess, which was done immediately, under the strictest aseptic and antiseptic precautions. When opened, it discharged two drachms of blood and pus; the wound was thoroughly irrigated with a 1 to 1000 solution of corrosive sublimate; a free incision was made, and drained by means of rubber tube and ligatures; then dressed with antiseptic gauze held in position by turns of a roller. During the operation the patient showed no signs of

tetanic spasm, only of pain such as would usually attend the opening of an abscess ; no anæsthetic was given ; medicine was administered at 7, 9, and 11 A.M. and 3, 5, and 7 P.M. ; on the night of the 14th the patient rested well, being disturbed by occasional paroxysms of pain.

September 15.—On redressing the foot and removing the tube, very little discharge on the dressings was found. Patient complained of dull, grinding pain in his body, extending down his left leg ; the wound showed very little signs of inflammation ; it was dressed antiseptically, and the nurse ordered to keep the dressings damp with the antiseptic solution. Abdominal muscles still rigid ; no trismus ; the patient was still unable to protrude the tongue normally ; was cheerful and talked rationally. The medicine was administered at 9 and 11 A.M. and 1, 3, and 5 P.M. The nourishment consisted of soup, rice-pudding, and some solid food.

September 16.—Patient was resting comfortably, having slept six hours during the preceding night ; the tetanic symptoms lessened, with long interval between spasms, but still complained of the dull pains extending all over his body ; temperature normal ; respiration 18 ; pulse 74 ; on dressing the foot, dressing showed no discharge except a little bloody serum ; the wound was thoroughly washed out and redressed as before ; medicine administered at 9 and 11 A.M. and 2 and 6 P.M.

September 17.—The patient was able to sit propped up in bed ; no paroxysms or spasm ; lessened rigidity of abdominal muscles, but

still complaining of the pains, especially in the limbs. Temperature, pulse, and respiration normal; medicine administered 9 and 11 A.M. and 5 and 7 P.M.

Saw the patient again on the 19th of September, and found his condition much improved; pains diminished and wound almost entirely healed; the patient, on attempting muscular movements, showed great muscular inco-ordination; all medicine was ordered discontinued; and the patient's bowels being constipated, he was ordered a saline purgative, and relieved on the following day by rectal enema.

Patient was seen again on the 22d; he was able to walk about the room by the aid of a cane, still complaining of pains in his limbs and soreness of muscles, and also of a condition of malaise. He was ordered easily-digested food, moderate amount of exercise, and, as no further attention was necessary, the visits were discontinued.

One remarkable fact in the patient's favor was the large amount of nourishment taken, also that the bowels were kept constantly open, never, under any circumstances, being over forty-eight hours without being moved.

The total amount of the bromides administered was fourteen and one-half ounces; chloral, three ounces, three drachms, and forty-five grains.

CULTIVATION EXPERIMENTS.

The experiments made from the case of traumatic tetanus described were from (1) blood collected on a handkerchief (not sterile) from a slight bleeding at the nose

(epistaxis), from which the patient suffered on the second day of the disease. The part containing the blood-stains was cut out and placed in sterilized water. After soaking for six hours, six tubes were inoculated with the fluid. In twenty-four hours, at a temperature of 80° F., the tubes showed slight growth, varying in color and form, showing the cultures to be contaminated. From each of the six tubes, tube-plates were made, which, in thirty-six hours, at a temperature of 80° F., showed numerous localized colonies of different growth. After development of each, stains were made, and the microscope revealed the pure cultures of cocci, the staphylococcus pyogenes aureus and albus, but the remaining slides showed mixed cultures of bacilli and cocci of different sizes and forms. From the tubes showing contamination, tube-plates were made, three from each tube, and, after development, five removals were made from each colony. These were cultivated from tube to tube until the eighth generation of each tube was reached, stains being made from each tube as it developed. By this method two more pure cultures were obtained,—*i.e.*, staphylococcus pyogenes citreus and proteus. The other tubes showed bacilli of different dimensions; tube-plates were made of these, and by removals, by scratch- and stab-cultures, two pure cultures were obtained, one of which grew both aërobic and anaërobic. From the odor of one, and by microscopic appearance, it proved to be the bacillus pyogenes fœtidus; and, after a series of removals and cultivation, both aërobic and anaërobic, by

stab-culture and by pure hydrogen growths, the other proved to be the bacillus of tetanus, as described by Nicolaiev. Stains were made from each culture, which, at the same age, from different tubes, showed the same microscopic appearance. These experiments were confirmed by Dr. David Bevan.

Two rabbits were inoculated with a solution from a pure culture of bacillus, both of which proved negative, neither manifesting any symptoms of the disease, although watched for eight weeks.

2. From blood obtained on opening the wound, which was done under strict aseptic precautions. The same process was gone through as previously described, and, after carrying to tenth generation, the same microorganisms were isolated, with the exception of proteus vulgaris. From each pure culture tube-plates were again made, which showed no new growths. By macroscopical comparison, they showed the same appearance as the ones previously isolated. The staphylococcus pyogenes aureus and albus afterwards proved their presence by the formation of an abscess, which has been described. Two rabbits were inoculated with the blood, but in both the writer failed to produce tetanus.

From the pure cultures of the bacillus, two rabbits and two guinea-pigs were inoculated. After three days, one guinea-pig manifested tetanic symptoms; there was slight abduction and stretching of the hinder extremity nearest the seat of the inoculation, the limb becoming completely stiff; there was muscular inco-ordination, the animal suffering from

clonic convulsions, which grew more frequent as the case progressed. The trismus was only slight, the animal taking food between the paroxysms. The animal could be thrown into violent spasm by a wave of air or by any sudden movement; these symptoms continued to increase, and on the third day the animal died. Blood and serum, and also portions of tissue from the point of inoculation were immediately inoculated into tubes, and another guinea-pig inoculated with a portion of the spinal cord (cervical region) of the animal dead of tetanus. From the tubes the bacillus of tetanus was isolated, but the experiment on the guinea-pig proved negative, the animal manifesting no symptoms of the disease. The other guinea-pig showed no symptoms of the disease. The guinea-pig which was not affected had been inoculated with pure hydrogen culture. According to Belfanti and Pescarolo, the virulence is diminished when cultivated in an atmosphere of hydrogen.

Of the rabbits, after eighteen days, one showed signs of muscular inco-ordination, first affecting the muscles nearest the point of inoculation; the convulsions were severe and frequent, marked trismus, and on third day of disease, and twenty-one days after inoculation, the animal died. From the cord and tissue the original bacillus of tetanus was isolated. On the twenty-second day after inoculation the other rabbit showed symptoms of the disease, and four days afterwards, twenty-six days after inoculation, the animal died. From this case the writer failed to isolate the bacillus of tetanus.

3. From the pus obtained from the abscess which formed on the patient's foot, by tube-plating and by removals, I obtained the micro-organisms of suppuration, and also the bacillus pyogenes fœtidus, and a bacillus which resembled the bacillus of tetanus; but the writer failed to produce tetanus in animals, either by inoculation of pus or of pure cultures obtained from the pus, although one guinea-pig showed symptoms of malignant œdema; in fact, it was well marked in the limb which was the seat of inoculation. It is a well-known fact that the bacillus isolated from pus obtained from a tetanic patient resembles the bacillus of malignant œdema, the same bacillus sometimes causing tetanus, and at others malignant œdema.

4. In the blood, after the patient had fully recovered from the disease, by careful tube-plating and removals, no bacillus of tetanus was found.

5. From a case of so-called idiopathic tetanus, which was in the wards of St. Mary's Hospital, the writer obtained a few drops of the patient's blood, but by careful cultivation no bacillus of tetanus was obtained.

6. From a case of traumatic tetanus, which died at the Episcopal Hospital. From the post-mortem the writer obtained some of the serum from the body; also portions of the cervical region of the spinal cord and medulla. Cultivations on agar-agar were made, from which the bacillus of tetanus was isolated. No inoculation of the pure culture obtained was made; but a small portion of the medulla, being emulsified in bouillon, was injected into a rabbit, which caused a series

of rapid convulsions, and in one minute the rabbit was dead. Post-mortem revealed nothing, except that it died a pulmonary death; the true cause was most likely ptomaine-poisoning or pulmonary thrombosis. All the experiments from the body of the animal proved negative. The experiment was repeated in two other rabbits with negative results, although these were inoculated with a portion of the cord two days after its removal from the body.

Experiments were also made with earth obtained from around the building where the patient was working when the foot was injured. From this the bacillus of tetanus was isolated, as well as numerous other microorganisms,—viz., staphylococcus pyogenes aureus and albus, staphylococcus pyogenes citreus, bacillus pyogenes foetidus, and proteus vulgaris. No inoculation of animals was made from the bacillus obtained from the earth, but macroscopically and microscopically it corresponded in every way with the bacillus of tetanus.

The period of incubation of the guinea-pigs was from three to five days; of the rabbits, much longer,—eighteen to twenty-two days,—with the one exception. In several of the rabbits, in from four to six days after the inoculation, they showed slight symptoms of the disease,—muscular inco-ordination, rigidity of limb nearest seat of inoculation; but in one to two days all these symptoms passed off, with no further manifestation. On post-mortem examination of the case previously mentioned no important pathological change was found; nothing, at least, but what would

occur in other diseases, the cord and brain being slightly congested. In the post-mortem examination of the animals no important or constant pathological alteration was noticeable in any organ or in the cord. Microscopical examination of the blood and internal organs was almost entirely negative; at least, nothing definite was learned. Upon examining the patient's urine, both by chemical tests and microscopically, it proved to be normal, except for a large increase in the amount of urea, it being double the usual amount. The urine was examined several times while the patient was in the height of the disease, with almost the same result.

From the animals inoculated, and before any symptoms appeared, blood was taken from the veins to the amount of one-half drachm; but cultivations from this failed to demonstrate the presence of the bacillus of tetanus. In the guinea-pigs the blood was taken in from twenty-four hours to three days; in the rabbits, at varying intervals, from twenty-four hours to sixteen days after inoculation. From the animals suffering from tetanus, blood was taken in varying amount, never exceeding one-half drachm. By cultivation from this, the bacillus of tetanus was found in only two cases,—one rabbit and one guinea-pig; all the others proved negative. But at the point of inoculation the bacillus was found, except in two cases; while the experiments with the blood, as before related, was not so constant.

Experiments with the blood, before inoculation was made, as well as those from the blood of the animal in which no symptoms

had developed, were negative. It has been asserted by Nicolaiev and Kitasato that the bacillus of tetanus is localized at the point of inoculation, and while Shakespear, Hock-singer, Deor, and others demonstrated the existence of the bacillus in the blood and internal organs; yet, out of twenty cases, in only three were they able to find the bacillus in the blood. From the writer's research in this case we must admit that it does exist in the blood as well as in the wound. Belfanti and Pescarolo failed in fifteen different cases to produce tetanus from the spinal cord of the animals that died of the disease. They also failed in some instances to find the bacillus at the point of inoculation. These same experimenters found that if the blood was taken immediately after death, the results were negative, but if they were to wait for six to twelve hours, they could also find the bacillus in the blood and internal organs. Their theory for this is that during life there was enough of oxygen in the blood to prevent the growth of the bacillus, and only at the time of death, in death's agony, it enters the blood, and, as the body is anaërobic after death, it then exists in all parts,—in the cord, blood, internal organs, and other tissues. Belfanti endeavored to prove that the bacillus does enter the blood, by inoculating several rats at the tip of their tails, and after from one hour to twenty hours cauterizing the root of the tail, but the animals died of tetanus, which, it is said, was due to the action of the bacillus of tetanus, while others claim that it was due to the action of the ptomaines in the blood. Rosenbach found the bacillus

of tetanus in the spinal cord of rabbits killed with tetanus. Nicolaiev, out of many observations, only once found the bacillus in the nerve (sciatic) near the point of inoculation, and only twice in the spinal cord.

As to the resistance of the spores, it was found that old cultures—three to four months old—retained their virulence, and from them new cultures could easily be obtained. Kitasato has also found this to be true where the spores were dried on silk. The bacillus has been obtained from the decomposed body of a person who died of tetanus even after a lapse of more than a year.

The bacillus of tetanus resists the action of other micro-organisms; even in tube-cultivation, where the growth is contaminated, the bacillus loses none of its virulency. Souchez-Toled showed that in blood kept in aseptic tubes the bacillus was found, and that it retained all its virulency. The writer was able to confirm this by the blood taken from the wound, from which, after five months, the bacillus was isolated. That the bacillus is present in the cadaver and in putrefying bodies was proven by the same experimenter and confirmed by the writer.

That, in order to induce tetanus, you must have an abrasion, has been definitely settled. Lorrani, Belfanti, and others found that the bacillus and spores may be drawn into the respiratory passages by inhalation, and even injected into the bronchial tubes, without producing tetanus. The pure cultures have been fed to animals without any result whatever; yet Betoli cites the case where slaves fed on the bull died of tetanus, and yet three

of their number suffered from the disease, and two died.

Thermal Tests.—The great resistance which the bacillus of tetanus has to heat has been well established. The writer exposed stab-cultures to a temperature of 200° F. for five minutes, and from this removals were made; out of ten tubes inoculated, nine showed growth in thirty-six hours. Again, a tube was exposed to 212° F. for five minutes, and removals made; out of ten, eight showed growth, and when exposed to 212° F. for ten minutes, out of ten removals, five showed marked growth. These experiments were verified by using cultures of different ages,—from eight days to three months. Those containing few spores were destroyed at 180° F. by exposure for twenty minutes, but those containing a larger number of spores were more resisting.

It was found that, in order to destroy the bacillus and its spores, a continuous exposure to a temperature of 212° F. for not less than thirty minutes was necessary. This only confirms the statements of Belfanti and Pescarolo, who found that an exposure of one hour to a temperature of 80° C. did not destroy the bacillus or spores. Kitasato exposed a pure culture to a temperature of 90° C. for one hour, and yet was able to make cultures from the tube; but, by exposing to a temperature of 100° C. from ten to twenty minutes, he claimed to have destroyed both bacillus and spores. Kitasato used the following method to obtain a pure culture of the bacillus. He exposed a mixed culture to a temperature of 180° F., at which

temperature the other micro-organisms were destroyed ; but the bacillus of tetanus being more resisting to heat, pure cultures were obtained. While this method is suitable for obtaining pure cultures of the bacillus of tetanus, it is entirely useless for obtaining any other organism which might be found with it, and is thus robbed of its scientific value.

Effects of Drugs.—Ten tubes of the pure culture of the bacillus on agar-agar were exposed to a solution of corrosive sublimate, 1 to 1000, for five, ten, fifteen, and twenty minutes, and three removals made from each tube, at each exposure, and without exception, in from twenty-four to thirty-six hours, every cultivation showed marked growth. Five tubes were then exposed to a solution of the same strength, for intervals ranging from one hour up to ten, and from these three removals were made from each tube at each exposure, and it was found that when exposed for ten hours or over no growth could be obtained. It was found that the spores even resisted its action longer. The experiments were repeated, bouillon being used. Seven tubes, each containing twenty-five cubic centimetres of the culture medium, were then inoculated with the bacillus of tetanus. After forty-eight hours the tubes showed marked growth ; each tube was subjected to solutions of corrosive sublimate, the first tube being exposed to a solution of 1 to 1000 ; the second, 1 to 2000 ; and so on up to 1 to 7000. After three hours, three removals were made from each tube. From the tube which was exposed to 1 to 1000 solution, no growths were obtained, and from the three removals from the tube ex-

posed to 1 to 2000, two showed no growths; the other removals all showed marked growths. These experiments showed the effect to be the same in liquid or solid media, and these results agree with those of Belfanti and Pescarolo.

2. The effect of carbolic acid was next tried; five tubes of the pure culture of the bacillus were exposed to varying solutions of carbolic acid, one, two, three, four, and five per cent. strength. After three hours, three removals were made from each tube, and after from twenty-four to forty-eight hours, all developed growths. After exposure for six hours, three removals were again made from each tube, and those exposed to the weaker solutions, one to three per cent.; all developed growths, but from those which were exposed to the four and five per cent. no growths were obtained. The experiments were repeated on bouillon with similar results, and the acid seemed to affect the bacilli and spores alike.

3. The hydrochlorate of cocaine was then used. Four different tubes were exposed to different strengths of a solution of the drug,—one, two, three, and four per cent.; after five minutes, three removals were made from each tube. After thirty-six hours, two tubes, which had been exposed to the one per cent. solution, showed slight growth, and one tube from the two per cent. solution. From the three and four per cent. solutions no growths were obtained. Two tubes were then exposed to a one and two per cent. solution for ten minutes; from each three removals were made, from which no growths developed. Five tubes were then inoculated from a cul-

ture, which had not been exposed to the action of the drug. These tubes were immediately subjected to a one per cent. solution of the drug. In twenty minutes the solution was removed, but the tubes failed to develop any growth; confirmatory experiments were made on bouillon.

4. The peroxide of hydrogen was next used. Ten tubes were exposed to the drug for twenty-four hours; three removals were made from each tube, all of which developed growths. Ten tubes were then exposed to the drug for forty-eight hours, and three removals made from each, and, without exception, all developed growths. The only effect noticeable was, that it liquefied the growth almost immediately on contact, a gas being evolved. These experiments were repeated on bouillon with the same results.

Five tubes were exposed to the fumes of bromine for twenty seconds; three removals were then made from each tube. Out of all the removals, four developed growths. The tubes were then exposed to the fumes for forty seconds, and three removals were made from each tube, all of which failed to develop any growths.

SUMMARY.

Although these experiments are largely confirmatory, at least, in many points, of what has been done by others, yet some important observations have been added; and, from the research made, it has been proven that Belfanti and Pescarolo were correct in their statement that the bacillus of tetanus was not an obligate anaërobe.

While the bacillus does not proliferate

more rapidly in an atmosphere of pure hydrogen, yet it lessens its virulency when deprived of oxygen, and from pure hydrogen cultures inoculation experiments are almost always negative. In this the writer confirms the observations made by Widal, Chantenesse, Tizoni, Babes, Pescarolo, and Belfanti.

From the laboratory experiments, it was found that from stab cultures the growth would extend out over the top of the medium in from five to ten days after inoculation. By removal from this, as aërobic growths, the development was uninterrupted; but if the removals were made from portions of the growths beneath the surface, the removal showed no growth until after the sixth to as late as the fourteenth day; yet the same bacillus could be cultivated, either aërobic or anaërobic. It is the belief of the writer that no micro-organism is purely anaërobic,—*i. e.*, acting as such in the body. One can scarcely conceive where, in the human economy, such an organism could find a suitable nidus for its existence and proliferation. This view is further substantiated by many continental observers. The bacillus grows best at a temperature of 98° F., but will grow rapidly at 51° to 71° F.

Of the eleven animals inoculated, five died of the disease. From these the writer failed to produce tetanus in other animals; in one case he failed to isolate the bacillus of tetanus from the dead animal. From the blood of the animals, while suffering from the disease, the bacillus was found in only two cases,—from one rabbit and from one guinea-pig; also from the traumatic case re-

ported. From the point of inoculation, the bacillus was found except in two cases. Experiments from point of inoculation and from the blood after inoculation, and before any symptom of the disease,—*i.e.*, during the period of incubation,—gave negative results. Neither could the bacillus be demonstrated in the blood of the animals inoculated but not taking the disease at all.

That the bacillus is polymorphous is clearly proven by macroscopic appearance of growths at different ages, and by microscopic appearance of stained cover-glass films. Its marked resistance to the action of heat is clearly proven, requiring a continuous temperature of 212° F. for not less than thirty minutes to destroy it. Its resistance to the action of the corrosive sublimate and carbolic acid is definitely established, the experiments with these drugs being confirmed by many experimenters, among the most noted of whom are Bel-fanti and Pescarolo.

Peroxide of hydrogen showed no marked effect on the bacillus, except it seemed to retard its growth; but, without exception, the tubes on which the experiments were conducted developed growths. As to the use of the hydrochlorate of cocaine, its action was almost one of a specific, as all the cultures subjected to the drug for five to ten minutes failed to develop any growth.

Growths exposed to the fumes of bromine for twenty seconds, with few exceptions, showed no growths, and when exposed for forty seconds no growths were obtained.

It would be necessary, in order to arrive at any definite conclusion as to the effect of

these drugs, to administer the drug to the animal suffering from the disease, and note its effect. As yet this has not been done, except that bromine was used locally in mopping out the wound in the case reported.

Treatment.—The disease being an infectious one, isolation of the patient is of great importance. As the wound is the seat of inoculation, thorough antiseptic measures must be employed. As a prophylactic precaution, all irritating substances must be removed. If the wound be closed, it should be freely incised, disinfected, and free drainage established. In the case reported, pure bromine was applied, with undoubted beneficial results. Too much importance cannot be attached to the nourishment of the patient, whose diet should be entirely of a liquid nature. If this be impossible by the mouth, then nutrient rectal enemata must be employed. The bowels must be kept open, under no conditions allowing thirty-six hours to pass without an evacuation.

The patient should be kept quiet in a darkened room, preferably by himself, and no one allowed in the room except the attendant. The room should be well ventilated, but no current of air should be allowed to strike on the patient, as even slight draught will suffice to produce a paroxysm.

The remedies which have been most successful are those which lessen the reflex function of the spinal cord, the most successful of these being the bromides and chloral, both given in decided doses, until their full physiological effect is produced. Thirty grains of chloral should be used, with sixty grains of

the bromide of potassium or sodium, and in two hours, if necessary, thirty grains more of the bromide may be administered. If the drugs are vomited, they should be given by the rectum, and, if necessary, the patient may be chloroformed until they are absorbed. Different remedies have been used with varied success, such as conium, atropine, nicotine, wine of tobacco, physostigmine, eserine, chloroform, alkaline baths, and hypodermic injections of carbolic acid.

Chloral and the bromides have undoubtedly the most marked influence upon the severity of the spasms. For the relief of the paroxysms, much can be done by application of cold to the spine.

Professor H. A. Hare, in his essay on "The Physiological and Pathological Effects of the Use of Tobacco," cites nineteen cases treated with tobacco, of which nine recovered. The drug was used in the form of fomentations, injections, and cataplasms, or given internally, nicotina, in doses of from $\frac{1}{12}$ to $\frac{1}{6}$ drop, or nicotine, in doses from $\frac{1}{2}$ to 3 drops every few hours.

Miller recommends cannabis indica pushed to narcotism.

Elliston highly recommends some preparation of iron, preferably the carbonate, in chronic cases.

Topez reports a case successfully treated with injections of morphine and cocaine, each five per cent. solution. Billroth strongly recommends narcotics, especially morphine and chloroform, also warm potassium baths, strong irritants to spine, large blisters, and the hot iron.

Treves recommends the use of chloral, in 15- to 20-grain doses, at onset of the disease, followed by bromide of potassium. He also suggests the use of cocaine to control reflex action. Brunauer's case of rheumatismal (?) tetanus, which he reports cured by pilocarpine, was also given chloral hydrate.

Moullin recommends, above all other remedies, chloral and potassium bromide. He also urges the necessity of keeping up nutrition and of keeping the bowels open.

Potter, in his article on "Special Therapeutics," in which he enumerates some twenty different remedies, shows the best results from chloral, combined with the bromides. Shaw and Tordeus each report a case cured by combined doses of chloral and potassium bromide. In both cases this was continued one month before a cure was effected.

Ore, of Bordeaux, cites one case where intravenous injections of chloral, after one or two repetitions, entirely relieved the paroxysms. Chopard, in his thesis on tetanus, enumerates one hundred and thirty-two cases treated with chloral hydrate, with sixty-nine cures. Tabbi, in 1871, thirty-two cases, with fourteen cured. Beck, one year later, recorded thirty-six cases, with twenty-one cured. Knechl, in 1878, one hundred and thirty-four cases, with seventy-nine cured.

Professor W. S. Forbes reports a case of traumatic tetanus cured by the continued use of amyl nitrite.

Hansen reports two cases successfully treated by morphine and amyl nitrite. Richardson, three successfully treated by amyl nitrite alone.

Coste, of Marseilles, successfully treated one case with sulphate of quinine.

Bright cites one case in which quinine afforded permanent relief.

Navarro, in 1869, reported seventeen cases treated with eserine, with success in twelve cases.

Of cases successfully treated by curare, Chassaignac, in 1854, reports one case; Wells, two, with one cure; Demme, twenty-two cases, with eight recoveries; Busch, eleven cases, with five recoveries.

Capozzi, Morra, and Gherini each report one case cured by curare.

Eilert, Halhouse, Wilkis, Wood, and Watson report one case each in which calabar bean effected permanent relief; while Ashdown, Spencer, and Dickerson had no success from the use of the drug.

Hunter was successful in two cases by using chloral and cannabis indica.

Delsae saved three out of four cases by opium and chloral; Wood, nine out of eighteen by chloral alone; Birkett, one case; Page and Morgan report one cured case each, treated by aconite. Franzolini reports one case cured after twenty-nine days' treatment, during which time four ounces of chloral and twenty-two grains of hydrochlorate of morphine were administered.

Johnston, of Baltimore, successfully treated several cases by means of hypodermic injections of conine.

Mattingly's traumatic case, following a crush of the finger, was relieved by amputation. Frederick, in 1837, reported two hun-

dred cases in which amputation was resorted to, with twenty-four recoveries. Curling, in 1835, reported seven recoveries out of eleven amputations; Paland, two cases, with one recovery; Yandell, seventeen cases, with ten recoveries; Early, in 1871, one case, with recovery.

Bartholow recommends excision of the cicatrix.

Buck reports one case in which dissecting out the scar afforded almost immediate relief.

Farrey, in two cases, divided the tissues forming the floor of wounds, followed by rapid disappearance of the tetanic symptoms.

Samuel Wood, in a case following compound fracture of the femur, divided the saphenous nerve, and the operation was followed by recovery.

Watson reports sixteen cases in which neurotomy was performed, ten of which recovered. Farrey and Murray's cases were entirely relieved by division of the injured nerve.

Base and Marinelli divided the musculocutaneous nerve for tetanus, following a gunshot wound of arm, and the patient recovered.

Edwards records an instance of recovery following the division of the short saphenous nerve, the original injury being a lacerated wound of heel, followed by sloughing.

Fayer's case, following a lacerated wound of the hand, was relieved by division of the median nerve.

The treatment of traumatic tetanus by

means of injections of the tetanus antitoxin of Tizzoni and Cattani by Dr. Rudolf Schwarz, assistant in the surgical clinic of Padua, is discussed in the *British Medical Journal* of January 2, 1892.

Tizzoni and Cattani claim to have succeeded in producing immunity against tetanus, even in animals susceptible in a high degree, and have shown that the blood serum exerts an antitoxic action, and is capable of producing immunity. The tetanus antitoxin is obtained in a solid state by the addition of alcohol to the serum, and by drying the precipitate *in vacuo*.

The antitoxin was used hypodermically, in doses of 15 to 25 centigrammes. Thus far four cases have been reported as treated with the antitoxin,—one by Gagliardi, of Molinella; one case by Dr. Pacini, in the hospital at Colle di Val d'Elsa, Tuscany; one by Professor Nicoladoni, in the surgical clinic of Innsbrück; and the fourth by Dr. Schwarz. The latter case was also treated by chloral, warm baths, injections of carbolic acid, and by division of the nerve.

The general treatment may be summed up as follows :

1. Disinfection of the nidus of development of the bacilli.
2. The elimination of the poisonous products of the bacilli from the system.
3. Drugs which are sedatives to the nervous system.
4. Excision of the cicatrix.

