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BY

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THE ANIMAL SUTURE; ITS PLACE IN SURGERY.

By HENRY O. MARCY, M.D.,
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Investigations upon the origin of means adapted to a given end clearly teach that active minds have already subjected the chief factors to careful analytical study, although certain phases of the problem are ever presenting themselves under new aspects. Dominated by such thought, Solomon taught that "there was no new thing under the sun," and it is quite probable that the animal ligature was known and used by the Egyptian surgeons at a period antedating this wise Jewish philosopher.

The connective tissue of animals was early utilized for a great variety of purposes when it was necessary to secure great strength and high tension. The Homeric poems afford familiar illustration. In the Odyssey, the strings of the old Greek harp are described as made from the twisted intestine of the sheep. The ancient Egyptian harp is said to have been strung in a similar manner. The celebrated Arabic writer, Rhazes, who practised in Bagdad, A.D. 900, describes the stitching of wounds of the abdomen with the strings of the harp, and Albucasis also mentions the stitching together of wounds of the bowel with a fine thread from the twisted intestine of an animal.

The careful student of the early history of surgery finds abundant evidence that the ligature was used as a hemostatic agent at a very early date. Celsus, at the end of the first century, describes the ligature as of ancient origin, and says that it was used by the Alexandrian school of medicine, with the teachings of which he seems to have been familiar. He advised placing two ligatures upon the vessel and dividing it between the points of tying. Galen recommended its use, and Vesalius, in the sixteenth century, mentions the ligature as a relic of the past, greatly underestimated

in value because of the lack of anatomical knowledge. Its first application in amputations, on account of gunshot wounds, was doubtless by Ambrose Paré. At this time, wounds were cauterized with boiling oil, in the belief that gunpowder in some way poisoned the wound.

Special studies, however, for demonstrating the value of the material used for ligatures do not appear to have been made in the early history of surgery. Indeed, there is little doubt that, whatever the material used, it was always considered as a foreign body to be ultimately eliminated from the wound, and the material, selected for its strength without special reference to the irritation which might be induced thereby, naturally commended itself in the form of thread, silk, or hemp, which was in ordinary domestic use.

To our distinguished countryman, Professor Physick, of the University of Pennsylvania, is undoubtedly due the honor of having first introduced what is known as the *animal ligature* into surgical practice. His ligatures were made of chamois leather, and he and the late Dr. Dorsey usually rolled their ligatures on a marble slab to make them hard and round. The advantages claimed for the ligatures by Dr. Physick were that, being made of animal matter, they would serve long enough to obliterate the artery and be speedily removed by the absorbents, thus avoiding the difficulty arising from a foreign body, however minute. These ligatures were used in this country to a great extent, and Sir Astley Cooper demonstrated their superiority in his own operations.

"Dr. Hartshorn used strips of parchment for his ligatures. My friend, Dr. H. G. Jamieson, Professor of Surgery in Washington Medical College, Baltimore, has for a series of years been employing the animal ligature in an extensive surgical practise. He has used it in many amputations of the limbs and of the mammæ; he has tied the carotid, the iliac, the femoral, the radial, the posterior tibial, the spermatic, and other arteries, with the buckskin ligature, and in no instance had secondary hemorrhage; and he states that he has never seen anything of his ligatures, and, of course, his wounds have generally healed by first intention. Dr. Jamieson gives to Dr. Physick the honor of having first introduced the animal ligature, but he contends that the practise of rolling, or drawing to harden the leather, is highly reprehensible. He advises to tie the artery with a buckskin ligature very soft and a little

broader than the thickness of the skin, taking care not to tie it too tightly. He states, as the result of his observations and experiments upon sheep, dogs, and other animals, that a capsule will surround the ligature, if the capillary vessels be not much disturbed, or the vessel will be surrounded by an abundance of lymph, and the ligature dissolved.

"The method of Ætius and Celsus, revived by Abernethy, of applying two ligatures and dividing the artery between them, Dr. Jamieson condemns as unnecessary, since by a single flat buckskin ligature, the artery may be obliterated without destroying its continuity. Hence, he opposes all indissoluble ligatures of whatever material; he declares it not only to be unnecessary, but highly hazardous to cut the inner coats of the vessel, as recommended by Jones, etc.; and agrees with Scarpa as regards flat ligatures; but, by the use of the buckskin, has no need, like him, to remove his ligatures on the fourth day. For a very able and interesting account of his views, which are of the highest practical importance, I would refer to the thirty-seventh number of the *Medical Recorder*, published at Philadelphia, for January, 1827."[1]

The limit of this paper necessitates only brief extracts, although the entire paper is worthy of careful study.

"We believe that the animal ligature will secure the patient from all these dangers except one, to wit, the awkwardness of the surgeon; and even in this respect the animal ligature is preferable, not requiring that precision of management essential to the cutting ligature. If the ligature is cut from the leather with care, it will always admit of being tied sufficiently tight, but can never be made to cut the coats, provided it is made of soft buckskin, and not hardened by drawing it. It is less likely to slip when somewhat insecurely applied, because, being elastic and soft, it is spread over a small space of the vessel, and almost immediately adheres by its glutinous properties. It lies more securely, while the cutting ligature, resting on a mere line, and having neither adhesive properties nor the advantage of a small vacuum between the vessel and the ligature, as is the case with the flattish, adhesive ligature, is more likely to slip off. Besides, as we cut off the ends close, there is no risk of pulling them away by an 'accidental jerk of the hand.' In support of these assertions, we have to offer the experience of several years' practice, during which we have used no other than the buckskin ligature, and no such thing as a secondary hemorrhage has ever occurred in our practice, extending alike to cases of aneurism, tumors, and amputations.

[1] Cooper's Medical Dictionary, sixth American edition. Edited by D. M. Reese, M.D. Vol. ii. page 130.

"We are, moreover, decidedly of the opinion that in no case whatever have we had reason to suppose that the healing of a wound, accidental or surgical, was delayed by our ligatures; we never see anything of them after their application." . . . "Mr. Cooper tied the femoral artery in a female, aged eighty, with a ligature of catgut steeped in water, which was cut close, and the wound was healed on the fourth day, and must, therefore, have healed by first intention.

"In many cases, we believe, the catgut would answer as well as the buckskin, but we are confident that a flattish ligature holds best and is most convenient. It may be proper to mention that this case occurred in 1817, three years after Dr. Physick's use of the leather ligature." . . . "If we are right in the opinion which we have just expressed, Dr. Physick is entitled to the credit of bringing into use the best ligature as to the material, but here his claim is at an end." . . . "Dr. Physick and Sir Astley Cooper have shown the advantage of using a substance which will serve as a ligature till the artery is obliterated, and be speedily afterward in the power of the absorbents, so that they will remove it. . . . We will now proceed to point out our own views, and endeavor to support them by experiment.

"First. We believe that with an artery sufficiently healthy to admit of its obliteration by the adhesion of its sides, it is best done by a ligature which will neither cut its coats nor strangulate, except in parts, the true *vasa vasorum*, so that the continuity of the vessel shall not be destroyed, although we obliterate its calibre.

"Second. We believe that if an animal ligature of the proper kind be properly applied the vessel will be obliterated, the wound may be healed by first intention, and the ligature will not cause suppurating inflammation; but in due time, being dissoluble, the whole will be removed by the absorbents. There will be no break of continuity in the artery, the *materia arteriarum* will be removed, and the vessel which, during the state of inflammation and the effusion of lymph, was converted into a cord, will pretty soon afterward be resolved to a flat string of white cellular structure."

"Experiment 1.—Twenty-two days after tying the carotid artery of a sheep with buckskin ligature the wound was found entirely healed, the artery obliterated, upon one side of which was a little yellowish matter which proved to be a portion of the ligature.

"Experiment 2.—Twenty-five days after tying the left carotid of a dog there was seen on either side of the vessel two little yellowish knobs, which proved to be the two ends of the ligature in the state of yellow pulp. The knobs were completely enveloped in a strong membranous capsule, the same capsule enclosing both knobs, and its fibres plainly seen crossing over the artery. . . . On the lower side where the coats were not cut, in splitting open the vessel to examine its interior, there was an actual adhesion of the leather to the inner coat. The string was softened into a pulpy consistence, and near the inside of the vessel was evidently covered with organized lymph, and extended along its edge on one side some distance. When the string was gently pulled, one plainly saw a delicate membrane, passing off

from the artery and ending on the string in fringed extremities. This attachment of the vessel by a new formation existed on both sides of the artery. The capsule covering the knobs, or ends of the string, was fully equal in strength to the outer coat of the artery, and therefore there was no tendency to hemorrhage."

It will be seen that in all the essentials the experiments of Dr. Jamieson, undertaken for a similar purpose, were not unlike those of Sir Joseph Lister, repeated half a century later; and the former at a period when so little was expected of the American people in the way of literary productions, to say nothing of scientific research, that one of England's famous critics asked, "Who reads an American book?"

Dr. Ephraim McDowell, in 1809, tied the pedicle of his first case of ovariotomy with a ligature of buckskin.[1]

In the history of ovariotomy in the United States, by the late Dr. Peaslee, it is stated that Dr. Nathan Smith, Professor of Surgery in Yale College, in 1821, tied the arteries with leather ligatures (narrow strips cut from a kid-glove), which were returned into the peritoneal cavity and the incision was closed, followed by recovery.

Dr. John Bellinger,[2] of Charleston, South Carolina, in 1835, successfully performed ovariotomy, tying two arteries in the pedicle with animal ligatures.

Dr. Thomas Young,[3] of Edinburgh, writes in 1813: "I have often wished to try ligatures, made of catgut, which might be absorbed." Professor Paul F. Eve,[4] of Nashville, Tennessee, wrote in 1876: "I have been in the habit of using the sinews of the deer, for ligating vessels, for forty years. I have never used carbolized spray. The tendons of the deer, dried and torn into shreds, and rolled into ligatures, are what I employ. They are absorbed; I have occasionally used them as sutures, but generally apply silk for this purpose."

These fragmentary experiences, drifting down to us through the

[1] It is probable that Dr. McDowell, and other operators later, made use of fine strings cut from the skin of the deer which had been tanned after the methods of the Indians, then, and for a long time after, in common use. These gave a ligature greatly superior to that cut from skins tanned by the modern methods.

[2] American Journal of Medical Sciences, 1837, vol. xxi. page 380.

[3] Introduction to Medical Literature, 1813, page 418.

[4] Transactions of the International Medical Congress, Philadelphia, 1876. Antiseptic Surgery, by John T. Hodgen, M.D., page 528.

years, teach that there was more or less blind groping after a something that should serve a better purpose than that which the routine of daily practice, in the use of the hemp or silken ligature, afforded. It was reserved for the present generation to make possible a scientific basis for the better consideration of ligatures and sutures in their application to the living structures. In the light of our present knowledge of surgical pathology, the opposition to the ligature in the days of Ambrose Paré, which we have been wont to attribute to the conservatism of ignorance and stupidity, is invested with a new and vital interest. The amputated limb, seared with the hot iron, as a hemostatic, a measure most barbarous and revolting, gave as a result an aseptic wound. Repair was necessarily slow and tedious, but abundant granulation supervened, before decomposition ensued, to protect from septic absorption.

The constricting ligature, the septic, pocketed wound, with little care as to cleanliness, gave such secondary fatal results that we are led to wonder that the innovation of the ligature, in the closing of the great vessels, became the established practice. Had it not been for the frightful dangers from secondary hemorrhage after the use of the cautery, slow healing giving imperfect results, it may well be questioned if even the indomitable spirit of Ambrose Paré could have made the innovation survive his own time.

A deeper philosophy sought solution of the problem, as to the causation of suppuration in wounds, and if its prevention was not within the possibility of the rule, rather than the exception. The studies of Pasteur, Tyndall, our own Jeffries Wyman, and others, undertaken for the solution of the problem of spontaneous generation, brought fruitage to the human race little dreamed of by these wise philosophers.

The genius of Mr. Lister seized upon the application of the thought, and with a patient, investigating spirit, and painstaking toil, worked out the fundamental factors of the *rôle* of ferments in wounds. It was not until rules could be formulated, based upon the scientific deduction that operative wounds should be free from suppurative processes, hitherto considered almost necessary concomitants, that the proper conditions for the study of ligatures and sutures were rendered possible. Of necessity in intimate association with the question of the treatment of operative wounds, arose, *de*

novo, a most interesting chapter devoted to the best means of controlling arterial hemorrhage.

It was clear that the hitherto prevailing method of ligation, leaving the ends of the ligature long, extending from the wound, by so much at least prevented primary union; while cutting the ligature short, and closure of the wound, were fraught ever with disastrous consequences, when the septic ferments were thereby deeply buried. When aseptically applied, the constricting silken ligature too often proved an irritating foreign body, to be ultimately slowly eliminated.

In retrospect, with present knowledge, what seems simple factorage of the problem proved extremely difficult of solution. The conservatism of thought, the prejudices of the large number of the surgical authorities of the time, wedded to present measures, misled by other phases of dominating thought—the so-called vital processes of inflammation, irritation, cell proliferation, etc.—engrossed the subject with many difficulties. The demonstration that fermentation and suppuration in a wound resulted from the introduction of a *something* from without, was the first real step of progress. To eliminate that something was the next problem for solution. It was clearly shown that the torsion of an artery to procure rupture and intrafolding of its interior coat, causes permanent closure of the vessel, and that the living structures, unpoisoned by germ infection, possess the power of easy disposition of the aseptic necrotic portion devitalized by violence.

Histological study demonstrated that the necrosed part no longer underwent the changes which had formerly been supposed necessary for the elimination of dead material, known as suppuration, gangrene, etc., but that the part becomes invaded by living cells which, little by little, produce a local change marked by early disappearance of the necrosed tissue. This naturally led up to the thought, if extraneous animal tissue could not be prepared in a way that, introduced into the vitalized structures, would be followed by a similar result.

Mr. Lister having determined that the safe rule of practice demanded the consideration of every wound, as one primarily infected by the omnipresent atmospheric germ, based as fundamental the principle of the treatment of every wound by agents capable of destroying ferments therein accidentally lodged—the so-called

antiseptic method of wound treatment. To this end he found carbolic acid in varying strength of solution eminently advantageous, pursuing his aërial enemies by impregnating the atmosphere immediately about the wound with a carbolic acid solution in fine subdivision, as spray.

Repeated experimentation taught that small pieces of dead tissue, preserved in carbolic acid solutions, incorporated into the living structures, were disposed of in a manner not unlike the necrosed portion of a twisted artery, and led to the inference that animal tissues properly preserved could be used for the constriction of vessels. In looking about for suitable material of animal type to be used as ligature, the catgut prepared for musical purposes naturally offered itself. It proved comparatively easy, by immersion for a considerable period in a carbolic solution, to render the material non-infective, but, as a soft, slippery strand, it lacked necessary qualities in which to make a secure knot, and by its early softening in the tissues, loosened and thereby failed to secure the end sought. A long immersion in an oily solution of carbolic acid, to which a very little water had been added, produced a material change of structure—a kind of tanning process thereby resulted, which gave to the material the quality of less easy softening in the tissues, as well as retaining a firm knot, which was ultimately disposed of by the surrounding structures.

I know of no series of experimental studies better worthy of admiration, or emulation, than Mr. Lister's experiments undertaken for this purpose upon the lower animals, which the laws of England necessitated his resorting to the Continent in order to make possible. The resulting changes, histologically shown to have taken place in ligatures applied to the vessels of the lower animals examined at different periods, taught that the cell proliferation at first enclosed, and later on penetrated, the carbolized ligature, until, little by little, it became replaced by living connective-tissue cells—a discovery the importance of which is scarcely fully appreciated, even to the present time. Mr. Lister's experiments were limited to the ligation of vessels, and there has resulted from his teachings the surgical treatment of the great arterial system with a safety hitherto deemed impossible. The larger vessels are now tied in continuity, in close relation to their bifurcations, even the greater trunks, with a seeming impunity little less than startling.

Returning in 1870 from my studies at Edinburgh under Mr. Lister, liberally supplied with a variety of the materials which he then advised in operative treatment, I not only made use of catgut for the ligation of vessels, but accident early furnished me the opportunity for a new application of the ligature, in the form of buried sutures. February 19, 1871,[1] I closed the ring, necessarily greatly enlarged for the reduction of a strangulated hernia, with deep sutures of catgut. This I did in order to retain the abdominal contents, because of a severe asthmatic bronchitis from which the patient was also a sufferer. The resultant permanent cure of the hernia, with a marked proliferation of tissue along the line of the buried sutures, led me to inquire if the sutures buried in the part had not been disposed of in a manner similar to that demonstrated by Mr. Lister, resulting about the catgut ligature surrounding the arteries.

I immediately instituted a series of experimental histological studies upon the lower animals, and demonstrated that, along the track of an aseptically buried suture, cell proliferation rapidly supervenes and that new cells invade the softened tissue, and *pari passu* with its absorption, a *living band of connective-tissue cells* replaces the whole line of the suture. If rapidly absorbed, the proliferated cells are minimized; as the process goes on more slowly the change becomes more distinctive until, in young animals, in ten to fifteen days all trace of the suture as such is lost. The value of such reinforcement of the tissue along the line of the sutures became at once apparent in their application to the cure of hernia, and, little by little, I early extended their use to the closure of wounds of every description, publishing, from time to time, my results.[2]

In the pursuance of my studies, I early had occasion to examine a great variety of the specimens of catgut offered in the market, although from the first I adopted what seemed to me the wise pre-

[1] A New Use of Carbolized Catgut Ligatures for the Cure of Hernia. Boston Medical and Surgical Journal, November, 1871, vol. viii. page 315.

[2] The Radical Cure of Hernia, by the Antiseptic Use of the Carbolized Catgut Ligature. Transactions of the American Medical Association, 1878.

Animal Ligatures. Annals of Anatomy and Surgery, 1881, page 232.

The Animal Ligature. New England Medical Monthly, June 15, 1883, page 387.

The Restoration of the Perineum by a New Method. The Physician and Surgeon, May, 1887, page 201; August, 1887, page 359.

caution of preparing my own sutures. In catgut there are, of necessity, certain inherent defects. Its method of preparation is not generally known to the profession, who have rarely questioned the product beyond the condition in which it is offered for sale prepared for the musician. The best of these varieties usually come from Italy, prepared from the intestine of the sheep of the mountainous districts. The small intestine necessarily undergoes maceration until the connective-tissue layer, which, as a loose fibrous sheath, unites the mucous and muscular coats of the intestine, is softened, and can be easily separated in a manner not unlike that practised in the preparation of the intestine of the pig for the making of sausages. This is split by a cork, armed with sharp blades, drawn through the circular sheath, dividing it into sections to produce the desired size. These ribbons are twisted, dried, and oftentimes sandpapered to give evenness to surface, and usually put up in little skeins from twelve to fifteen feet in length—the catgut of commerce.

The connective tissue cells of the fibrous coat of the intestine are irregularly disposed, the fine fibrils more commonly crossing diagonally to the longitudinal axis of the intestine, a wise distribution of this strengthening portion of the intestine to allow considerable change in its shape. When carefully examined, under a low-power lens, the fibres are seen to be irregularly interlaced, not unlike a strip of cloth cut diagonally. The gut, even in the dry state, has a perceptible yield on tension, and every musician knows the care requisite to protect his strings against moisture. Frequent allusion is made in the classics to the care demanded of the bowman in this respect, when it was customary to string the weapon with animal products.

Macerate a piece of catgut until it can be easily unfolded, the above condition is readily apparent. Moreover, its division is rarely uniform, and, when sandpapered, the removal of the irregular projections causes oftentimes large abrasions, or rents. No matter how prepared for surgical use, ultimately the result obtained will depend, in considerable measure, upon the integrity of its structure, since the component cells are, little by little, separated by the penetration of the new proliferating tissue. The long maceration in the first stage of preparation, remaining for a considerable time a putrefying mass, necessarily damages the material, not only by softening the adhesion of the cells, but infecting them with bacteria; and in

the use of the catgut for all surgical purposes it is important, as the first step in preparation, to destroy any germ infection that may remain. After this has been effected, no method which I have tried gives a result equal to that formulated by Sir Joseph Lister.

"Dissolve one part of chromic acid in four thousand parts of distilled water, and add to the solution two hundred parts of pure carbolic acid, or absolute phenol. In other words, I use a one-to-twenty watery solution of carbolic acid, only that the carbolic acid is dissolved not in pure water, but in an exceedingly dilute solution of chromic acid. But, minute as is the quantity of the chromic acid, it exerts, when in conjunction with carbolic acid, a most powerful effect upon the gut. The first effect of the addition of the carbolic acid to the chromic solution is to change its pale yellow color to a rich golden tint. But if the liquid is allowed to stand without the introduction of the catgut, it changes in the course of a few hours to a dingy reddish-brown, and a considerable amount of gray precipitate is formed. If, however, catgut about equal in weight to the carbolic acid is added as soon as the ingredients are mixed, the liquid retains its brightness, and the only change observed is a gradual diminution of the depth of the yellow color; the precipitate, which I presume still occurs, taking place in the substance of the catgut. As soon, therefore, as the preparing liquid has been made, catgut equal in weight to the phenol is introduced into it. If you have too large a proportion of catgut, it will not be sufficiently prepared; if you have too small a quantity, it may run the risk of being over-prepared. At the end of forty-eight hours catgut steeped in such a solution is sufficiently prepared. It is then taken out of the solution and dried, and when dry is placed in one-to-five carbolic oil. It is then fit for use."[1]

It improves by age and is better not to be used until after it has been several months in carbolic oil. The preliminary disinfection of the gut is of the first importance, since preservation of the hardened structure in the carbolized oil may not penetrate to the destruction of bacteria within the strands.

I have elsewhere published[2] in detail the micrococcal infection developing only along the line of the buried sutures, of four consecutive surgical cases, giving evidence upon which I deduce the conclusion that it could have been only to this inherent defect of the catgut, which had been selected from freshly opened preparations, preserved in carbolic oil, which were sent me from London.

[1] In several instances I have known sutures to be ruined by a misunderstanding of the above directions of Mr. Lister, much too large a quantity of chromic acid having been used. It may simplify to remember the quantity is about four grains of chromic acid to a quart of a saturated solution of carbolic acid.

[2] The Surgical Advantages of the Buried Animal Sutures. Journal of the American Medical Association, July 21, 1888.

"A great deal of difficulty had been experienced from time to time in the use of catgut, in the formation of stitch abscesses, and the following methods of preparing silk and gut were put to trial: . . .

"The original catgut, as taken from the carbolic oil, was cultured and found to show organisms in every case." . . .

"It is difficult to understand how germs can live that have been immersed in an alcoholic solution of 1 to 1000 corrosive sublimate, but it is suspected that the hardening of the catgut, prior to complete sterilization, shuts up within the substance of the gut a certain number of organisms, which remain latent until they are placed in living tissues; when the catgut swells, the germs are set free, and stitch abscesses result. . . . Reverdin reports a series of experiments in reference to the sterilization of catgut. He found that crude catgut which had not been kept in fat to preserve it, which was exposed for four days to a constantly increasing temperature, maximum 140° C., and then placed for a day in oil of juniper and kept in alcohol, was aseptic. This he had used clinically for eighteen months with perfect results.

"V. Boret has cultured the catgut preserved by Reverdin in bouillon, glycerine, and sugar at different temperatures, and found that there was no reaction at the end of six weeks. Boret has tried the other methods of sterilizing catgut, and found that bacteriologically and clinically they failed. . . .

"CONCLUSION.—Small catgut was found, as ordinarily prepared, to be always sterile; large catgut, never.

"As catgut is too valuable a material to be discarded, the writers would advise the method of Reverdin, by heat, which is bacteriologically a good one."[1]

Dr. Macewen[2] published a very interesting article giving his method of preparing catgut, so as to render it more reliable, by immersing it in a watery solution of chromic acid—1 to 5—and adding one part of this to twenty of glycerine. Remove in two months and preserve ready for use in carbolic acid and glycerine—1 to 5. By varying the strength, gut is prepared possessing different degrees of resistance to absorption in the tissues. My own experience of animal sutures prepared in this way has not been satisfactory.

I have also used catgut prepared in oil of juniper and kept in alcohol, but think it inferior to chromicized gut.

Owing to these inherent defects in catgut, in common with other

[1] Ligature and Suture Materials. Medical communications, Massachusetts Medical Society, article xxv. By H. L. Burrell, M.D., and G. R. Tucker, S.B.

[2] Chromic Gut—Its Method of Preparation and Behavior in Living Tissues. William Macewen, M.D., Glasgow. Annals of Anatomy and Surgery, 1881, page 128.

surgeons, I was led to inquire if there were not other animal tissues better suited for surgical purposes.

The tendinous structures of the body present the connective tissue cells parallel and firmly united to each other. Although generally thus disposed, there is considerable variety in the arrangement of the cells, making a parallel separation much more uniform in some tendons than in others. As far as possible, a detailed investigation of animal tendons of sufficient size has been prosecuted with varying success.

The tendons of the hind leg of the moose and caribou, soaked in a sublimate solution until soft, were the first tested. A considerable portion of the tendon may be subdivided sufficiently fine for sutures, in length from fifteen to eighteen inches.

Dr. John H. Gilman,[1] of Lowell, called my attention to tendons from the whale, stating he "had used them with great satisfaction in the ligation of vessels." Specimens were sent me from Provincetown four feet in length and of sufficient strength to draw a cart, but the ultimate fibrils were interlacing, while the whole tendon was interspersed with adipose cells. I obtained ligatures also from the whale tendon which were made under the direction of Dr. T. Ishigure,[2] of Tokio, Surgeon-in-Chief of the Imperial Japanese Army. The mode of preparation is given as follows: "First, a whale's tendon is dissected by the points of needles, and teased out until the fibres look very like those of hemp. Secondly, the longest and finest fibres among them are selected, and they are then spun together as ordinary silk thread." There can be no question ligatures thus prepared are very serviceable, but the specimens furnished me were not suitable for sutures.

The Sioux Indian women in the Northwest taught me, in 1882, their manner of sewing buffalo skins with the tendinous structures derived from the fascia lata of the buffalo, which they preserve for this purpose by drying and smoking. During the present summer, I obtained from Mr. Harry Adams, of the Hudson Bay Company, in Winnipeg, Manitoba, specimens from the fascia lata of the moose prepared by the Indians of the far Northwest Territories, as a substitute for that from the buffalo now extinct, called by them

[1] Boston Med. and Surg. Journal, Oct. 1880, page 433.

[2] The Whale Tendon Ligature as a Substitute for Lister's Catgut Ligature. E. A. Otis, M.D. Boston Med. and Surg. Journal, Sept. 30, 1880, page 331.

Astis. They use it in the dry state, stripping it as they sew, occasionally wetting it in the mouth. Good tendon sutures in any quantity can be obtained from this source. My specimens, however, are not more than fifteen inches long, and are quite inferior to the kangaroo tendon. Some years since, a distinguished Russian surgeon sent me similar specimens from the reindeer, finely divided and slightly twisted. These I prepared and used with satisfaction.

In 1880, Dr. S. G. Simmons, of Charleston, S. C., sent me admirable specimens of tendons from the tail of the fox squirrel, with the statement that he had often used them for delicate surgical purposes with great satisfaction. This tendon is composed of exquisitely beautiful parallel fibrils, which can be subdivided without fraying to the size of fine threads. Their extreme length, however, scarcely exceeds nine inches. Reasoning from comparative studies, it seemed to me highly probable that the kangaroo should possess a tendon, similar in quality, traversing the entire length of the tail. Through the kindness of the late Mr. Alonzo H. Newell, of Boston, for many years a prominent merchant in Australia, I obtained some most excellent specimens. At the International Medical Congress held in London, in 1881, in a paper[1] upon the cure of hernia, I mentioned the use of the tendon suture from the kangaroo and other animals as especially to be commended. Reference to my recommendation of the kangaroo tendon and its value in surgery was some time later made in an Australian publication. This came to the notice of Dr. Girdlestone, who wrote me that he had used kangaroo tendons for some years with great satisfaction, and had published the results.[2]

The tendons should be taken from recently killed animals, quickly sun-dried, and kept dry until ready for further preparation. This prevents primary decomposition, which we have pointed out as necessary in the preparation of the catgut. When soaked until soft they are easily separated as fine as desired, with remarkably little waste, and give threads from the size of hairs upward, and from eighteen inches to two feet in length, exceptional specimens being even considerably longer. The kangaroos

[1] The Cure of Hernia. Transactions of the International Medical Congress, 1881, vol. ii. page 446.

[2] Tendon Ligatures. T. M. Girdlestone. Australian Medical Journal, Melbourne, 1877, vol. xxii. page 356.

are so numerous as to make their skins of commercial value, being sent to the United States in lots each of many thousands, yet it is only with the greatest difficulty and expense that I have succeeded in securing tendons sufficient for my own use, although I have sent *carte blanche* orders to various parties in Australia. I was informed they could be obtained in London, but two years ago the enterprising firm of Grosvenor & Richards, of Boston, searched the London markets without avail. Quite recently, Felton, Grimwalde & Co., of Melbourne, Australia, wrote me that they regularly keep in stock tendons prepared for surgical purposes. I cannot doubt that, at an early date, surgeons will be furnished with the kangaroo tendons, which I fully believe are in every way greatly to be preferred to catgut.

In an interesting article published in 1882 by Dr. Girdlestone,[1] he emphasizes the use of the tendon entire as a ligature rather than suture. "In their preparation they should not be removed from the tail *en masse*, but one at a time, without force, as if split longitudinally they could not be relied on. Every diameter that was required was attainable, so that there was no occasion for splitting; neither should two or more tendons be twisted together, as it destroys their flattened form." The advantage claimed is, that they may be used as flat rather than round ligatures, constricting the artery with less liability of cutting the vessel.

Dr. Dudley,[2] of Texas, has written a most interesting article upon the use of the tendon of the lepus, or mule-eared rabbit, as a material for ligatures and sutures. Dr. Dudley does not state the portion of the animal from which he obtains the tendon, but describes them as, "an aponeurosis of muscles rolled upon each other, susceptible of being torn into minute threads, if so desired." He first had occasion to use the tendon of the lepus as a suture, in the fresh state, in 1881, finding he had no silk in his pocket-case. He has continued the use of these tendons with the greatest satisfaction to the time of his report.

Dr. Bernes[3] published an interesting study upon animal ligatures

[1] The Surgical Uses of Kangaroo Tendons. T. M. Girdlestone, M.D., F.R.C.S. British Medical Journal, February 18, 1882, page 228.

[2] Animal Ligatures and Sutures. H. W. Dudley, M.D., Hillsboro, Texas. Transactions Texas State Medical Association, 1884, page 133.

[3] Animal Ligatures. By Joseph Bernes. Philadelphia Medical Times, August 8, 1874, pages 708–11.

in 1874. Although his experiments were not conducted with the care demanded to-day, yet they are still of interest and importance as original studies. They include a large number of experiments upon the lower animals with gut, both carbolized and uncarbolized, peritoneum cut into strips and rolled, as recommended by Dr. Agnew, and beef tendon dried, split into fine shreds and twisted, as well as silk, which was used as a standard of comparison.

"The extreme non-irritating properties of the tendon, coupled with its capacity for fine division, render its slow absorption of decided advantage, since a vessel can be secured with a strand of it so fine as to produce no irritation, and yet sufficient time elapse before its disappearance to render any danger from secondary hemorrhage as remote as in the employment of silk, by which the vessel is usually severed in the course of a very few days. . . . It will be seen that the tendon ligature fulfils all the requirements set down at the beginning of this paper for a substitute for the material now in use. . . . It is, beyond all doubt, ultimately absorbable, so that a ligature of it can be cut off close to the knot and left in the wound. The tendon is by no means so absorbable as catgut."

The use of animal suture requires the same and the only precautions that are requisite to the successful application of the ligature. It *must be* in *itself aseptic;* it must be *aseptically applied* in an *aseptic wound.* When thus applied, the range of its uses may be extended to all operative wounds. It is difficult to conceive if any possible advantage is to be derived in the treatment of any aseptic wound by leaving it open—the so-called open-wound method.

Before the *rôle* of bacteria in wounds was understood, when it befell from chance, rather than scientific care, that primary union supervened, it is easy to understand how many who dreaded the daily experiences of fermentative material retained in pocketed wounds, not only refused to rely upon drainage with occasional irrigation, as a sufficient preventive of septic poisoning, but they insisted, as far as possible, upon allowing no recess in which purulent material could gather. In order to effect this, the lips of the wound were separated and kept apart by antiseptic dressings, so that the wound might heal by granulation from its very base. This is manifestly safer for the patient, and the result attained is not unlike that from the repair processes which supervene in the secondary healing of infected wounds; but those who advocate this method thereby confessedly acknowledge their lack of confidence in the

modern methods of wound treatment, and their inability to protect wounds from infection.

In rare instances, it has been claimed that the resulting cicatricial union gives an increased strength to the parts involved, an opinion which it seems easy to show is unscientific and contrary to the general consensus of surgical opinion.

If it is correct to assume that the theoretic perfection in wound-treatment, which it is the ambition of the surgeon to attain, means a reunion of the divided parts, the anatomical relationship to be restored and maintained, then the suture holds a higher place in surgery than ever hitherto considered.

If the suture itself is replaced by vitalized structures, then its proper application becomes of the highest importance, the value of which the profession is only recently seeming to begin to realize. Given, as illustration, the joining of a divided retracted nerve, or muscle, and its restoration to subsequent perfect usefulness; the sundered cervical tissues after a hysterectomy where the delicate joining of the peritoneum allows no open wound for hemorrhage or absorption; the reunion of the abdominal wound after laparatomy, where the peritoneum is independently united by a layer of buried sutures, and where the linea alba, or the muscular aponeurosis of the sheath of the recti is carefully rejoined, since the adoption of which method I have not had a single case of ventral hernia; or, again, in the amputation of large tumors of the breast, where the remaining tissues are carefully coapted, so that retention and pocketing of fluid are impossible, rendering drainage not only superfluous but harmful.

I would not underestimate the importance of drainage in wounds that are necessarily septic, and in this class of wounds there is no advantage to be gained in the attempted use of the buried suture.

The recent discussions upon the uses and advantages of the buried animal suture are both interesting and profitable. A valuable article, based upon original observations, was published in Germany by Dr. Werth,[1] in which he advocates the use of catgut, in the repair of the perineum, as an interrupted buried stitch. These were taken between one and two centimetres apart, the gut tied and cut short

[1] Ueber die Anwendung versenkten Catgut-suturen bei Operationem in der Scheide und am Damm. Dr. Werth, Kiel. Centralblatt für Gynäkologie, November 8, 1879, page 561.

upon the knot. In cases where the surfaces to be coapted were large, a second row of stitches was similarly placed. Great care was exercised in making the application under aseptic precautions, and most satisfactory results were obtained.

Schroeder[1] repeatedly used catgut as a buried continuous suture and commended it highly. Dr. A. Martin[2] is less enthusiastic, and says:

"I, myself, have tried catgut sutures according to Werth five times; the results were not favorable, but I must admit that in two of these cases the catgut may have been too old."

Doléris[3] recommended knotting the thread, from time to time, of the continuous suture, and believes the buried gut is absorbed in seven or eight days. He reported to me when in America, in 1887, a still further satisfactory use of buried animal sutures.

Bröse[4] writes approvingly of buried catgut sutures rendered aseptic by a corrosive sublimate solution and preserved in absolute alcohol.

Dr. C. B. Keetley[5] published a valuable article upon the uses of the buried suture. He ascribes to Professor Esmarch's assistant, Neuber, and Professor Küster, much valuable original work with the use of the buried suture, especially in amputations, thereby doing away with drainage. He writes:

"Küster read his paper at the last meeting of the Society of German Surgeons. In the discussion that followed, Esmarch having stated that, with these sunk sutures, drainage-tubes could be altogether dispensed with, he was asked, 'What, after excision of the hip?' He thereupon answered shortly and decisively, 'Yes.'"

In conclusion, he says:

"I have to say that it is only in strictly antiseptic surgery I would venture to recommend the use of these sutures, but that in the case of all surgeons who have faith in the antiseptic theory and practice, they will find in buried sutures an effective and beautiful addition to their methods."

[1] Centralblatt für Gynäkologie, July, 1885.
[2] Martin, Diseases of Women. English edition, page 170. 1888.
[3] Archives de Tocologie, February, 1885.
[4] Centralblatt für Gynäkologie, 1883.
[5] The Buried Suture. C. B. Keetley, M.D. British Medical Journal, May 2, 1885, page 880.

Mr. John Wood[1] writes in regard to femoral hernia:

"Latterly, I have found the use of tendon ligature so satisfactory, that for this operation I prefer it to wire. The wound usually closes over it and heals by adhesion at once, and there is not the pain and inconvenience of the withdrawal of the wire. So far the endurance of the tendon, when buried in the tissues, has been long and satisfactory enough to maintain the cure, which has been watched, noted in some cases about two years."

My own experience with the buried animal suture commenced with its use in the case of hernia above referred to, in 1871, and this, with other cases where the cure was believed to be referable to the buried suture, was first published in the *Boston Medical and Surgical Journal*, November, 1871. In 1878 I contributed a paper on the subject at the meeting of the American Medical Association. In 1881 a further contribution upon the same subject, emphasizing the value of the tendon suture, was published in the *Transactions of the International Medical Congress.*

These and various other articles giving the results and surgical advantages of the use of the buried animal suture and its adaptability to special purposes, were reprinted and widely distributed to the profession, both in Europe and America.[2]

If the premises, which I have assumed in the early discussion of this paper, are correct—that a properly prepared aseptic animal suture, aseptically applied, retains its strength sufficiently long to hold at rest the coapted parts until primary union is effected, and then itself slowly disappears, after having fulfilled this function, to be in a measure replaced by vitalized connective tissue—there can be little wanting to attain the theoretic perfection in the suturing of wounds. The first observations which I published, perhaps

[1] Lectures upon Hernia and its Radical Cure. 1885.

[2] Animal Ligatures. Annals of Anatomy and Surgery, July, 1881, page 232.

Cure of Hernia by the Antiseptic Use of Animal Ligatures. Transactions of International Medical Congress, 1881.

Animal Ligatures. New England Medical Monthly, June, 1883.

The Restoration of the Perineum by a New Method. Journal of the American Medical Association, Oct. 27, 1883. Reprint.

The Surgical Advantages of the Buried Animal Suture. Journal of the American Medical Association, July 2, 1885. Reprint.

The Perineum; its Anatomy, Physiology, and Methods of Repair after Injury. Philadelphia: William J. Dornan, 1889.

A Treatise on Hernia. The Radical Cure by the Use of the Buried Antiseptic Animal Suture. Published by George S. Davis, Detroit, Mich., 1889.

naturally, provoked only incredulity, and the results were considered at best accidental. The evidence already accumulated and presented to the profession, by a great variety of observers in different parts of the civilized world, is now sufficient to substantiate this claim.

Silk has justly held a high place in the esteem of the profession because of its exquisite perfection of preparation, and it has been claimed, if rendered aseptic, that it was equally safe as a buried suture. Mr. Lawrence,[1] the distinguished English surgeon, made many interesting and valuable studies upon the ligation of vessels with silk cut short and buried in the wound. His efforts to minimize what he considered the irritating foreign material are very instructive:

"The method I have adopted consists in tying the vessels *with fine silk ligatures* and cutting off the ends as close to the knot as is consistent with its security. . . . Of the silk which I commonly employ, a portion sufficient to tie a large artery, when the ends are cut off, weighs between one-fiftieth and one-sixtieth of a grain."

He adds:

"Although I have not yet ascertained what becomes of the pieces of ligature after the wound is united, I have never seen abscesses or any other bad symptom occasioned by them."

Mr. Lister early experimented very carefully with silk, steeped in various substances, immersed in melted wax and carbolic acid to render it aseptic. In further proof of its innocuousness, it has been claimed that it is also an animal product, and that the tissues should be capable of assimilating it into their own structures. My distinguished friend, Dr. Pancoast, of Philadelphia, believes the fault lies, in large measure, in the introduction of lead during its preparation, and that hence the use of iron-dyed silk is greatly to be preferred:

"It is innocuous, does not produce suppuration along the track of its thread, and the color adds much to the ease with which it may be distinguished for its removal."

Advantages, doubtless, but the necessity of removal emphasizes the fault in material, and not in the color or the skill of applica-

[1] New Method of Tying the Arteries in Aneurism, etc. William Lawrence. Medico-Chir. Trans., vol. vi. page 156. Cooper's Med. Dictionary, vol. ii. page 129, 1836.

tion, which renders it manifestly unfitted for use as a buried suture.

The general verdict of surgical opinion, and it has certainly been often repeated in my own experience, is that aseptic silk, aseptically applied, may be incorporated into the tissues, but remains encysted, and often, after a considerable lapse of time, causes irritation and is expelled as a foreign body.[1]

The mode of application of the buried suture is of the greatest importance. Without exception it should be a continuous suture, since thus used more perfect coaptation of the parts can be obtained while, as far as possible, knots should be avoided. It is important to minimize the material consistent with careful coaptation. It should join like tissues, periosteum to periosteum, muscle to muscle, deep fascia to deep fascia, and skin to skin, after deep incisions of all kinds. It should support the parts always without any constriction of tissue. Having secured these ends, it matters comparatively little by what manner of stitch it is applied. The opinions of operators will be modified in preference for the methods to which they have become accustomed.

For certain purposes it has seemed to me a manifest gain to include the tissues by a double suture, taken by means of a needle with eye near the point, which allows the ends of the suture to be introduced through the same puncture from opposite directions. This of necessity encloses, and should coapt, but *must not constrict*, the tissues involved. The advantages of this stitch are most apparent in certain operations, and I have especially advocated its use in the closure of the canal in hernia, in suturing the pedicle of uterine and ovarian tumors, and in perineorrhaphy.

For wounds in the intestine, and in resection, I have repeatedly used a double layer of tendon sutures, the Lembert stitch, taken as a continuous, not an interrupted, suture. The finer curved Hagedorn needles are the best. The needle pierces the peritoneum as in the Lembert stitch, entering and emerging about two lines from the sides of the wound. This intrafolds and coapts the peritoneum evenly. In resection of the intestine, or if an incised wound is long, I take a second layer about one-fourth of an inch outside of

[1] New York Medical Journal, September 14, 1889; pp. 296 and 297. Discussion upon silk ligatures and sutures buried in wounds.

the first, coapting more peritoneum and thereby burying entirely the first line of sutures. Post-mortem intestine thus joined will hold water, and in a well-vitalized subject the effused lymph, in a few hours, entirely covers in the affected part. The advantages of this method are simplicity, rapidity of operation, avoidance of knots, a minimum of manipulation and of injury of the tissues involved, even and sure closure of the parts—all of which are of the first importance to a good result, as well as to the security and non-irritability of the tendon suture.

As far as possible, the suture should cross the wound at right or acute angles and not lie parallel with it. For the coaptation of large wounds, as in amputation of the breast, I have found it a decided advantage to use a running stitch, taken from side to side, both ends left externally free, tension upon which evenly coapts the sides of the wound. Fine tendons are thus introduced in two, three, or more layers, commencing at the very base of the wound.

The skin is evenly coapted by a blind running stitch taken from within outward through the deeper layer only. This evenly unites the edges of the skin, while the suture itself is buried beneath it. The wound is dried, dusted with iodoform, covered with a layer of iodoform collodion, reinforced by a few fibres of absorbent cotton. The ends of the deep lines of the running sutures, after sufficient tension has been exercised to produce coaptation, are fixed in the collodion and cut off.

The subsequent dressing matters little; a soft pad of cotton may give comfort by its support, but if the wound is *aseptic* at the close of the application of the iodoform collodion, it being presupposed that each step has been taken with modern aseptic precautions, *primary union will supervene, and drainage is not only needless, but is a positive disadvantage and danger.*

Aseptic wounds thus treated give really a simplicity of detail which seems surprising when contrasted with the clumsy and bungling antiseptic dressings which this method—the aseptic application of buried animal sutures—is destined to supersede. In conclusion, the *rôle* of the buried animal suture may be accepted as a corollary to antiseptic surgery, upon the basic principles of which it is founded as a scientific deduction.