division is made by a sawing motion. The tendon is felt to yield suddenly and often with an audible snap. The knife is then withdrawn and the minute opening is closed by pressure with a compress of gauze.

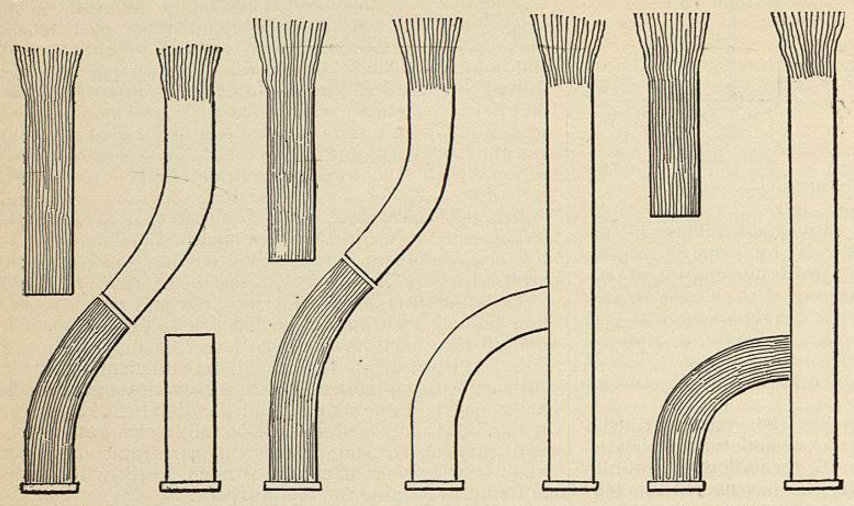

FIG. 4636. FIG. 4637. FIG. 4638.

FIGS. 4636, 4637, AND 4638.—Methods of Functional Transfer. (After Vulpius.) Shading represents paralyzed tendon.

The operation should be done with all aseptic precautions. The wound in the tendon heals by the organization of the blood clot between the divided ends; these soften and become fused with the new fibrous tissue. For some time this has the appearance, both gross and microscopic, of scar tissue. After about three months the new tissue can scarcely be distinguished from the old. Immediately after the division of the tendon the necessary correction in the position of the part is made, and fixation is usually accomplished by plaster of Paris applied over the aseptic dressing. The operation is most frequently done upon the tendo Achillis for club-foot, either congenital or paralytic; the tibialis posticus and anticus, and the plantar fascia are often divided for the same purpose. Tenotomy may be indicated for the lengthening of any contracted muscle, or when it is desirable for any reason to exclude the action of a muscle, *e.g.*, the tendo Achillis, in the correction of anterior bow-leg.

In some instances, and especially in spastic paralysis, the overcorrection of deformity causes such extensive separation of the divided ends of a tendon that their subsequent union may be in doubt. For the avoidance of this, plastic tenotomy or tendon lengthening is often done. An incision is made over the tendon, which is then split longitudinally for a distance equal to the amount of lengthening desired. Incisions are then made at right angles to this at either extremity of the longitudinal cut and in opposite directions (Fig. 4635, *B*). The figure shows the method of uniting these flaps. For the tendo Achillis, Bayer has proposed a subcutaneous method in place of his original plastic tenotomy. This consists in cutting through half the width of the tendon above and below subcutaneously. Upon making forcible dorsal flexion of the foot the tendon will now split lengthwise and the effect be the same as in Fig. 4635. It has the additional advantage of avoiding adhesion between tendon and sheath. The writer has done the operation repeatedly with satisfaction.

The greatest advance in tendon surgery during the last twenty years has undoubtedly been in the field of tendon transplantation. In this operation the whole or a part of one tendon is engrafted upon or united with the whole or a part of a second tendon. In this way we may either transfer the function of the one to the other, or divide it between the two. The essential indication for performing the operation is a disturbance of the equilibrium between the muscles controlling a joint. This may be due to paralysis or weakening of certain of them, or, in some instances, to the excessive activity of others. It is, of course, assumed that this disturbed equilibrium is incapable of spontaneous recovery or not to be corrected by simpler means. The feasibility of the procedure depends, moreover, upon the persistence of a certain total of muscular power, and its success will to a considerable degree be measured by the amount of this. Before proceeding to describe the technique of the operation and the various combinations from which we may choose, it will be well to discuss in some detail the indications for its performance. In doing so, indebtedness is acknowledged to the admirable monograph of Vulpius ("Die Sehnenueberpflanzung," etc., Leipsic, 1902).

The first group of cases to be considered as calling for tendon transplantation comprises those in which the muscular disability is of traumatic origin. The traumatism may involve the muscles directly, as by incision or subcutaneous rupture of the tendon, or, indeed, the loss of the tendon by suppuration or injury. Tendon transplantation should be considered for these cases, however, only when a very long time has elapsed since the injury, making the finding of the central end of the tendon exceedingly difficult or impossible, or rendering it likely that the muscle belly has degenerated to such a degree as to unfit it for use. Otherwise tendon lengthening by the plastic method, as before described, or by means of silk strands, should be considered the ideal. Traumatisms of peripheral nerves, such as the musculo-spiral, in which for similar reasons direct repair is not feasible, may also call for tendon grafting. In all of the beforementioned conditions it is to be borne in mind that tendon grafting is a procedure of second choice, to be done only in the event that direct repair by suture is excluded.

By far the most frequent indication for the employment of transplantation of tendons is paralysis of central origin, either spinal or cerebral. The largest class of these cases results from acute anterior poliomyelitis. It is well known that in such cases the paralysis, quite extensive to begin with, is recovered from during the first few months, so that after a year has passed there remains an involvement, of more or less circumscribed extent, of permanent character. We have then to deal with paralysis of certain muscles or groups of them, the remaining ones of the limb possessing normal power. In this event deformities are likely to develop, unless prevented by treatment, because of the lack of antagonism to the normally innervated muscles. These latter being made to share their power with the paralyzed muscles, equilibrium may be restored to the affected part, deformity prevented, and a considerable gain in the total power achieved by adaptation to the increased function. In those unfortunate cases in which flaccid paralysis of all the muscles of a part persists, or in which the paralyzed greatly overbalance in number and strength the unaffected ones, the operative stiffening of the joint, *i.e.*, arthrodesis, offers far more than operation upon the tendons. On the other hand, it has been observed after tendon transplantations that muscles which were paretic or atrophic from lack of use have under the new functional conditions regained their usefulness, so that the sum

total of muscular power, after operation, was considerably above what was anticipated. Whether in a given case arthrodesis will be preferred to transplantation or treatment by braces to either of these, will depend largely upon individual experience and judgment. Occasions, furthermore, arise in which these methods may with advantage be combined. The various forms of spastic paralysis, both spinal and cerebral, have also been treated by tendon transplantation with signal benefit. Of the cerebral cases only those should be chosen, however, in which the mental condition of the patient is good.

In the treatment of paralytic deformities already developed, the overcorrection of these should, as a rule, precede the operation upon the tendon. In any paralytic case transplantation should be considered only when likelihood of spontaneous improvement is no longer apparent.

Finally, the operation has been done for a number of deformities not of paralytic origin. Thus, to prevent the tendency to flexion after arthrectomy, or excision of the knee, or that which frequently occurs after the cure of tuberculosis or other severe arthritis of this joint, implantation of the hamstrings into the quadriceps tendon has been done with success. Likewise in severe cases of pes valgus or plano-valgus the operation has had its value demonstrated.

In order to decide upon a plan of operation it is necessary to know which muscles are paralyzed and which are not. This must be decided by careful observation of the patient and the voluntary movements of the part, and also by the electrical reactions. It is not to be forgotten, however, that the atrophy of disuse in certain muscles, caused by the paralysis of some of the more important ones of the part, cannot be recognized in this way; but for this purpose ocular inspection of the muscle substance is necessary. In contrast to the dark red of the normal, the paretic fibres of inactive but non-paralyzed muscles are pink of varying shade, while the paralyzed ones look yellow or yellowish-white, according to the amount of fatty degeneration. The complete design of the operation may have to be deferred for these reasons until such inspection has been made.

In the performance of the operation perfect asepsis is a prerequisite. When the tendons to be united are near to one another, a single incision parallel to them may suffice. When they are separated by a somewhat greater space, a slanting cut may be advantageous; but when the distance is considerable multiple incisions may be called for; these may also need to be made quite long for the inspection of the muscular substance. The tendon sheaths should be treated as conservatively as possible.

The combination of the tendons may be done in a number of ways. The simplest method is by lateral anastomosis. In this the continuity of both sound and paralyzed tendon is preserved; both are freshened and united by lateral apposition; tension being secured by drawing the paralyzed tendon proximally, the sound one in the opposite direction. The method is available only when the tendons lie in contiguity.

The second method is that of functional transfer (Figs. 4636, 4637, and 4638). In this the sound tendon is cut through completely, and is sewed to the whole or a part of the paralyzed tendon. This presupposes that the sound tendon is either useless or even harmful in its action, as by it the peripheral stump of the tendon is unused. This fault may, however, be overcome by uniting the distal end of the sound tendon with a sound neighbor. Finally we have functional partition, in which only a part of the sound tendon is joined to the paralyzed one (Figs. 4639 to 4642). This has the great advantage of conserving the function of the sound muscle through the uninjured part of its tendon. The figures show the methods by which functional transfer and functional partition may be achieved. The shaded tendon represents the paralyzed structure. Which of the methods will be chosen will depend upon the functional importance of the unparalyzed tendon which is to be used; upon its size, *i.e.*, whether a slip may be taken from it large enough to sew securely; and upon other conditions which present themselves at the time of choice. It is always preferable, when possible, to graft tendons of similar function; for example, an extensor upon an extensor. This need not of necessity be done, however. In doing functional partition it is desirable that the split in the tendon be made as near the muscle substance as possible, and that it be continued by blunt separation of fibres into the muscle belly for a short distance. This is done in order to achieve as much functional differentiation of the two parts as possible.

While the tendon is being cut through it should be held by means of clamp forceps, so as to prevent retraction into its sheath after complete division. In displacing the tendon from its old into its new position it is desirable that it shall be placed under the deep fascia, if possible, in order to minimize the likelihood of adhesions. Drobnik's suggestion to pass the tendon beneath the other tendons of the part may, however, be regarded as involv-

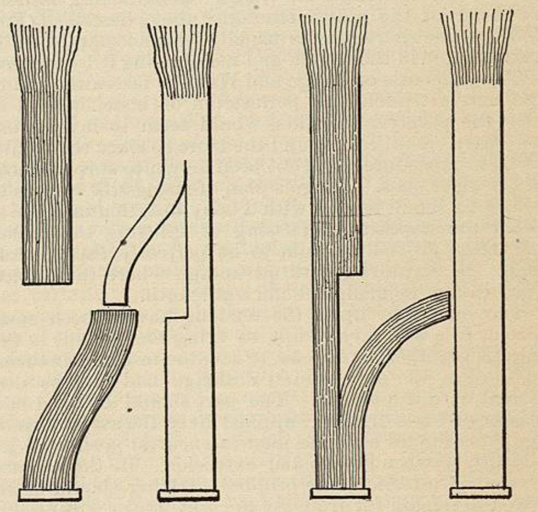

FIG. 4639. FIG. 4640.

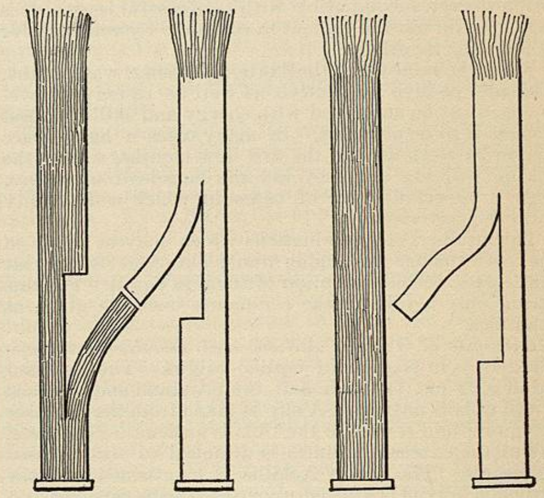

FIG. 4641. FIG. 4642.

FIGS. 4639 TO 4642.—Principal Modes of Functional Partition. (After Vulpius.) Shading represents paralyzed tendon.

ing an unnecessary amount of disturbance. It is highly important that the new course of the tendon be a fairly straight one; this requirement should be borne in mind in choosing the tendon and the point at which it is cut through. In grafting extensors upon flexors, or the reverse, the tendon may in the forearm and leg be carried through the interosseous space instead of around the limb.

The suture should be made under a certain amount of tension, and should be capable of withstanding considerable force. This is best accomplished, ordinarily, by passing the end of the divided tendon through one or even two buttonholes in the other tendon and securing it by a number of sutures. When two divided ends are to be joined, this is done, as above described, under tendon suture. Silk is by all means the best material to use for the suture, as it can be made truly aseptic, and will retain its strength sufficiently long. In a small proportion of cases sutures will afterward work their way out without jeopardizing the result of the operation.

In order to satisfy the two rules, that the tendon suture should be under tension and that it should be done under slight overcorrection of any pre-existing deformity, it will often be necessary to do tendon lengthening on some contractured muscle, such as the tendo Achillis, and tendon shortening on others. Lengthening is done by means of the plastic tenotomy above described (Fig. 4635), while shortening is usually best accomplished by taking a fold in the tendon and maintaining it by sutures.

The proposals of Lange and Wolff to fasten the end of the active tendon into periosteum or bone, instead of into the paralyzed tendon, would seem to involve unnecessary complication, and the more so since the results of these procedures have not been shown to surpass those of the older ones. Lange's plan of using silk strands to connect a sound tendon with a bony insertion in order to avoid the necessity of incising or splitting the tendon has been proved by him to be perfectly feasible. It might be employed with advantage where the tendon graft cannot be made of sufficient length.

The operation upon the tendons having been completed, it is well to attempt to bring the wounds in the sheaths together, or at least to sew the fascia over them. In closing the skin wound drainage had best be dispensed with if possible. The part should be fixed in a plaster-of-Paris dressing, applied over the aseptic bandage; this should hold the joint in a neutral position, *e.g.*, midway between flexion and extension. In the absence of wound infection, the original dressing should be allowed to remain for from six to eight weeks. Suppuration will usually place the result in great doubt. It is not, however, incompatible with a successful issue. It is best to maintain the patient in complete recumbency for at least one month.

After the removal of the fixation dressing, warm baths, massage, passive and active, as well as resistive movements, must be employed with energy and skill if fullest success is to be obtained. In many cases a light brace should be worn during the first few months, so that the act of walking may not tax the muscles too greatly. This is especially true of cases in which a deformity had been corrected.

The number of combinations which may be made in the performance of tendon transplantations is so great that space forbids mention of them in detail. For this reason only a few of the commoner ones are given as examples.

Paralysis of Tibialis Anticus and Tibialis Posticus.—The foot is in position of equino-valgus. The extensor hallucis is cut through and the proximal end is sewed to the tibialis anticus. A slip is taken from the extensor communis and sewed to the tibialis anticus. The distal end of the extensor hallucis is attached to the extensor communis. The tendo Achillis is lengthened, and the peroneus longus is grafted upon the tibialis posticus.

Paralysis of Gastrocnemius.—The foot is in position of calcaneo-valgus. The proximal ends of peroneus longus, flexor digitorum, and a slip from the tibialis posticus are implanted upon the tendo Achillis, which itself requires to be shortened. The distal end of the peroneus longus may be attached to the tendon of the peroneus brevis.

Paralysis of Extensor Communis and Peronei.—The foot is in position of equino-varus. Redressement of the deformity. Extensor hallucis sewed to extensor communis digitorum. Tibialis posticus severed and proximal end attached to peroneus brevis. A slip from tendo Achillis is attached to the peroneus longus.

While tendon transplantation is by all means to be considered a very great advance in the treatment of partial paralysis and of paralytic deformities, unreasonable things should not be expected of it. The most satisfactory results by far are obtained when only one or two muscles are paralyzed, and here the cure may under favorable conditions be practically perfect. When a number of important muscles must be substituted for, much less is usually accomplished. A better position of the limb, making the wearing of apparatus easier, because of simpler needs for it, is all that is frequently accomplished, and it is likely that in some cases arthrodesis would be of more beneficent effect. The success of transplantation depends, however, not only upon the selection of the proper muscles for grafting and a correct operative technique, but in no less degree upon attention to even the minor details of the after-treatment. The full benefit of the operation is usually not to be observed until some months afterward, and the total improvement is sometimes not gained until a period of as much as two years has expired. Sometimes benefit from the operation is found to be transitory; a few months afterward the patient is found to be in the old condition. In this case careful investigation will sometimes disclose the cause of failure in improper selection of energizing muscles, and one may with hope of success resort to secondary operations.

Albert H. Freiberg.

TERATOLOGY—derived from the Greek word *τερατολογια* (*τερας*, monster + *λογια*, tell)—in its broadest application is that department of biology which treats of the malformations or abnormal growths in both the animal and the vegetal kingdom. In the more restricted and usual sense of the term, as suggested by the elder Saint-Hilaire, in 1822, teratology includes the consideration of the graver malformations resulting from deviations in the normal development of man and other animals occurring at some period before birth.

It is evident that no sharp demarcation can be drawn between the many slight developmental variations giving rise to the numerous anomalies, or *hemiterata*, affecting various parts of the body and the more serious defects appropriately classed as malformations; with the latter, however, is associated the existence of disturbances of form and function which more or less profoundly affect the well-being of the organism.

Malformations may be grouped as *primary* and *secondary;* the former include those produced by arrest or deviation of the fundamental processes of development by which the animal body, or its parts, originates; the latter embrace those that result from disturbances of organs or parts, the early development of which has progressed normally until adversely impressed by some secondary influence.

Malformations presenting marked change or distortion from the normal appearance of the embryo or fœtus are termed *monsters.* In these the external characteristics are usually associated with structural defects of such gravity that the organism is incapable of maintaining an independent existence after separation from the sources of maternal nutrition. A conspicuous exception to such inability is seen in double monsters, which, notwithstanding their striking peculiarities, sometimes, as in the case of the famous Siamese twins, live, grow, and even thrive for years.

History.—An intelligent interpretation of malformations is so dependent upon an adequate knowledge of the processes of normal development that the evolution of teratology from the crude and fanciful speculations of the past into a recognized department of biology, founded upon a sound and rational basis, is largely the record of the progress of embryology itself.

The appearance, in 1759, of the epoch-making *Theoria generationis* of Caspar Friedrich Wolff marks the beginning not only of a true conception of normal development, as a progressive differentiation and specialization of a primarily simple germ-mass, but likewise of a just appreciation of the causes leading to abnormal formations.

From the earliest times the occurrence of congenital malformations may well be imagined as having arrested the attention and exacted the speculation of philosophers of all ages; objects of such deep general interest could not escape the keen scrutiny of Aristotle (384–332 B.C.), and to him we are indebted for the earliest discussions of the causes and the manner of production of such abnormalities.

Notwithstanding the interest with which these defective beings were regarded, over two thousand years elapsed before their true nature began to be suspected during the early half of the eighteenth century. Previous explanations of the production of monstrosities consisted of confused and fanciful assumptions, often grotesque in their absurdity, in which supernatural influences, the benign or baneful exercise of divine power, the impressions wrought by heavenly bodies, the blighting influences cast by unholy spirits and by witches, sexual congress with the lower animals or with Satan himself—"coitus cum diabolo" being an accepted factor even as late as Martin Luther and Ambrose Paré—all found accredited place in the category of potent causes of monstrous births. A detailed consideration of such idle speculation need not here detain us; the reader interested in a fuller account of these curiosities of medical literature may be referred to the interesting *résumé* of past theories contained in Ballantyne's paper on "Teratogenesis."[1]

Following, although tardily, the more accurate trend of anatomical investigation inaugurated by the genius of Vesalius and the enthusiasm of his pupils, the progress of teratology during the seventeenth and eighteenth centuries is marked by the passing of old traditions and the dawn of a rational conception of the significance of malformations as evidenced by the increasing number of accurate descriptions of these variations by competent observers. An adequate interpretation of malformations was manifestly impossible at a time when the fundamental facts concerning normal development were still to be recognized.

The discovery of the mammalian ovum by de Graaf, in 1672, and of the spermatozoa by Hamm, three years later, supplied the basis for the bitterly contested discussions of the two factions—the "ovists" and the "animalculists"—which, however, met on common ground in the acceptance of the doctrine of "evolution" which assumed that gestation resulted in the expansion and unfolding of the perfectly developed body, preformed but of infinitesimal size. These principles when directly applied to the explanation of malformations, as they were by many, led to the conclusion that such defects must result from malformed germs—an admission irreconcilable with the generally conceded adaptability to purpose of nature and a divine Wisdom. In order to meet these objections, the influence of mechanical disturbances, as well as of external pathological conditions, upon the unfolding germ was assumed by the more conservative. Even the philosophical Haller failed to appreciate the importance of the views advanced by Wolff, who, recognizing the fundamental truth that each new being is formed by individual development and differentiation of the primary simple germ, declared malformations to be the results of abnormal variations of the formative energy which under favorable conditions produced the perfect being. While in the main accepting the correctness of the then current doctrine of preformation, Haller presented for the first time a critical analysis of the relation of the known causes of abnormal development to the facts established by observation as gleaned from his own rich experience; he must be regarded, therefore, as one of the founders of scientific teratology.

The closing years of the eighteenth century, and the opening decade of the next, witnessed further advances in the study of malformations in the accurate investigations into the anatomical peculiarities of many abnormalities by Sömmering, Autenrieth, Tiedemann, Blumenbach, and others; Sömmering in particular was fortunate in recognizing the fact that congenital defects were not capricious aberrations, but that in their production they followed definite laws.

The services of Meckel to embryology in securing to Wolff's later papers their merited recognition, by translation into German, were also shared by teratology, since his keen appreciation of the truth of Wolff's "Epigenesis," as opposed to the long-accepted evolution theory, enabled Meckel to regard the production of malformations from an advanced standpoint. As an ardent believer in the dynamic causes of malformations, Meckel sought to explain the majority of defects as the result of disturbances of formative energy, attributing to an early arrest of development the prominence which his own researches suggested.

In 1822, four years after the completion of Meckel's "Handbuch der pathologischen Anatomie," the name of Saint Hilaire appears which, represented by father and son, has become inseparably associated with the study of congenital defects. The "Traité de Teratologie" of the younger, Isidor Geoffroy, Saint Hilaire, published in 1837, presented a most elaborate and systematic consideration of malformations in which the various forms of deviation are described and grouped with such completeness that even at the present day many of the features and names of St. Hilaire's classification find recognition by the latest writers. Although influenced by the opinions of his father to regard mechanical influences as the most potent cause in producing malformations, the fuller appreciation and the emphatic statement of the truth that certain typical forms of variation are continually repeated are among the benefits derived from the teachings of this eminent French teratologist.

Among the immediate results of the establishment of the cell doctrine by Schleiden and Schwann, in 1837, were not only renewed investigations and rapid advances pertaining to normal development, but also more searching inquiries into the mode of production of malformations in the light of these newer views. The contributions of Bischoff (1842), Vrolik (1849), Panum (1860), and Förster (1865) mark the beginning of a new era in teratological literature; the last-named author, in particular, proposed a classification upon an embryological basis which, in a modified form, may serve the purposes of to-day. Among the more recent systematic works on teratology may be mentioned those of Ahlfeld (1880), Taruffi (1881–95), Hirst and Piersol (1891), Guinard (1893), and Marchand (1897).

The deep interest which the causation of malformation has always excited could not fail to suggest attempts to produce artificially monstrosities as aids in solving the problems connected with the mode of production of these variations. Even before the appreciation of the fundamental truth that malformations arise as disturbances and deviations of the normal processes of development, the elder Saint Hilaire succeeded in producing abnormalities by incubating hens' eggs placed in unusual positions, thus meriting the distinction of being the founder of experimental teratology, to the results of which we are indebted to many most suggestive and important data. Liharzik, Panum, Dareste, Schrohe, Koch, Gerlach, O. and R. Hertwig, and Richter are among the investigators whose experimental studies yielded positive proofs of the disturbing effects of mechanical, chemical, thermal, and other influences. Within the last ten years the important experimental studies of Roux, Born, Driesch, Wilson, O. Schultze, Windle, Morgan, Schaper, and others have added much valuable information relating to embryological mechanics and to the formation of developmental variations.

It will be seen from the foregoing brief historical sketch that the advancement of teratology as a science may be divided (according to the predominating influences) into three periods: