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Notes on Military Orthopaedics.

**V. TRANSPLANTATION OF BONE, AND SOME
USES OF THE BONE GRAFT.**

BY

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INJURIES inflicted by modern instruments of warfare are so often associated with loss of considerable portions of bone that it is necessary to bring together various known means of replacing these defects. The present paper aims at giving a brief account of my experience of the grafting of bone.

Clinical experience in recent years justifies the expectation that a bone graft will grow and fulfil the purpose desired by the surgeon if the operative technique is appropriate and scrupulous attention is paid to asepsis. Before dealing with the practical difficulties to be encountered, brief reference must be made to various theories which have been advanced concerning the growth of transplanted bone.

Three of the theories may be mentioned :

One which has been widely held in Europe is that, when a bone graft is transplanted, the grafted bone always dies and is absorbed, and that any new bone formed in its place is laid down by the periosteum, which is the only part of the graft which really survives.

The second is the well-known view of Macewen that the new bone is formed by the proliferation of osteoblasts within the bone itself, and is quite independent of the periosteum, which is only a limiting membrane.

The third theory is that the graft is not osteogenetic, but merely acts as a suitable and appropriate scaffolding along and through which new capillaries and granulation tissue can grow, taking with them osteogenetic cells from the living bone ends, between which the graft is placed.

Recent investigations definitely prove that bone transplanted even into the abdominal wall may grow, and that this may happen whether periosteum alone or bone alone is transplanted.

McWilliams, of New York, whose investigations are thorough, concludes that the survival of the graft depends on the establishment of an efficient blood supply, and that the blood supply is more quickly and efficiently established when periosteum is transplanted with the grafted bone.

I advise that, whenever possible, it is best to transplant periosteum with the bone, and further, to be sure that the graft should also contain part of the endosteum.

Every surgeon knows that in simple comminuted fractures portions of bone must often be entirely, or almost entirely, cut off from their usual blood supply, but that necrosis of these fragments is extremely rare, while in the presence of toxins of bacteria, as in septic compound fractures, more or less necrosis is very prone to occur even in portions of bone still connected with their blood supply.

It is therefore safe to conclude that whether the osteogenetic cells are derived from periosteum or from bone, scrupulous asepsis is essential to their welfare; that if they are not poisoned by septic toxins they can survive on exuded lymph or plasma for a reasonable period while a new blood supply is being established; and further, that the open cancellous medullary aspect of the bone and the periosteum both furnish convenient means of access for

the new blood supply, and should be retained in the graft whenever it is possible.

It is important to remember certain further facts, which are established beyond doubt. First, that bone taken from one of the lower animals and grafted into man very rarely lives, even with the most careful technique. Secondly, that bone transplanted from one individual to another only lives in exceptional cases. These, therefore, are methods which cannot be recommended. Finally, it is established that autogenous transplantation of a portion of the patient's own bone from one portion of the body to another is fairly constantly successful if the conditions are suitable and the technique correct. The nature of the technique and the conditions found suitable will appear in the subsequent parts of this paper.

Professor Tuffier's experiences in relation to the transplantation of ovaries are interesting and instructive. He found that when ovaries were removed, it was possible to retain the internal secretory influence of the ovary by implanting a healthy portion of one ovary in the abdominal wall. If the patient's own ovary was employed it almost invariably survived and became tender at each subsequent monthly period. In cases in which no part of the patient's ovaries could be used, he tried borrowing an ovary from another woman on whom ovariectomy had to be performed. In every case this transplantation from one individual to another failed.

There are other facts which should be kept in mind when repairing bony defects. For example, if a bridge of periosteum can be preserved, osteogenesis, or new bone formation, is much more likely to occur, and the gap will be filled with greater rapidity than when no bridge is possible. Stiles's cases of subperiosteal resection for tubercle are evidence of this.

Since the survival of implanted bone is dependent on the establishment of circulation within it, it follows that necrosis is less likely to occur in small fragments than in large pieces, when the periosteum cannot be preserved. It is therefore a good practice to scatter small fragments of bone along the site of the defect, for the cells in them can live for some time on exuded plasma; the new blood supply will reach them in a few days.

**GENERAL CONSIDERATIONS AS TO TRANSPLANTATION OF
BONE.**

In performing transplantation of bone to replace a defect in the continuity of a long bone the surgeon has to keep certain points in view, and in all must follow Nature's rules.

1. Nutrition of the Graft.

In order to ensure the nutrition of the graft it is essential to observe the following points:

(a) *Perfect haemostasis* in the bed in which the graft is to be laid. A mass of blood clot round the graft endangers its life, for this blood clot must first be "organized" before the new capillaries or granulations can reach or grow into the bone graft to supply it with blood.

(b) *Perfect asepsis*, for toxins, if virulent, will almost certainly cause the death of the bone cells in the graft before a protective vascularization can occur.

(c) *Preparation of the bed* in which the graft is to lie. It should be freshened, so that rapid adhesion and organization may take place between the graft and surrounding tissue. Moreover, the soft tissues should be brought round the implanted bone.

2. Union of the Graft.

The union of the graft with the ends of the bones between which it is placed can be helped in a number of ways. The ends of the bone should be opened up and prepared for the reception of the ends of the graft. It is desirable that some part of the graft should be in contact with the vascular medullary cavity. Sometimes it is possible to push the graft straight into the open medullary cavity (Fig. 1). As a rule I avoid the use of plates and screws, as they tend to delay union. Various methods of fixing grafts will be mentioned later.

FIG. 1.—Graft pushed into open medullary cavity.

Perfect immobilization is an important factor in securing early vascularization and union. It is quite true that a certain amount of mobility at the seat of a fracture increases the output of callus, but this is of a vicious and really useless type. It is produced merely by osteogenesis occurring in the increased exudate caused by tearing and injuring the granulation tissue which is being produced to unite the fragments of bone. It is much more reasonable to keep the part immobile until union is firm and has begun to ossify; then the next stage mentioned below comes into play to strengthen the union.

3. The Growth of the Graft.

The growth and development of the graft so that it can perform the function of the bone it replaces is best promoted by a modified or guarded exercise of the function of the bone, for then the bone cells respond to the stresses to which the part is subjected, and build according. This is known as Wolff's law, which is an essential foundation of all surgery of bones and joints. This law is familiar to all surgeons; but it will not be out of place to quote it here: "Every change in the formation and function of the bones, or of their function alone, is followed by certain definite changes in their internal architecture, and equally definite secondary alterations of their external conformation in accordance with mathematical laws." It follows from this that when the graft and the bone have begun to unite firmly the union will become stronger if a certain amount of functional use is allowed, provided it is not violent enough to tear up or break the union. Thus in a graft in the leg or in the forearm the patient is encouraged to move the toes or fingers while the part is still in splints, so that the slight traction of the muscles on their origins round the site of the graft may produce a physiological stimulus to increased growth.

In the next stage the splints adapted must allow more active use, while at the same time guarding against strain which might cause a "fracture" at the seat of the graft. Thus in the case of the lower limb an ambulatory splint is allowed while the part is still firmly controlled by local splints.

THE USES OF BONE GRAFTS IN MILITARY SURGERY.

1. To Replace Bone Destroyed by Infective Processes, such as Acute Osteomyelitis.

As an instance of bone grafting after osteomyelitis and of the extraordinary vitality of the transplant, I would relate the following facts: Several years ago I was consulted in the case of a youth (A.B.) with advanced osteomyelitis of the tibia. I cut down along the whole length of the site of the tibia, and found that the shaft had completely disappeared, and the periosteum also. When I had scraped away all putrid material, there remained little except the epiphyses and exposed muscles. A long sinus probe was fixed lengthwise between the epiphyses in order to maintain the distance between them, and the wound was allowed to granulate. Several months after the wound had healed and the probe had been removed I transplanted a long strip of tibia from the

sound limb. This rapidly grew in thickness. The patient was discharged from hospital, and gradually discarded all supports. Seven months later he was knocked down one day, receiving a blow on the leg which broke the transplant, and I possess interesting radiographs of the callus exuda-

FIG. 2A.—Case of A. B. Osteomyelitis of tibia: condition after removal of necrosed bone. (Sketch from skiagram.)

FIG. 2B.—Case of A. B. Probe to hold end of tibia apart during healing of wound. (Sketch from skiagram.)

FIG. 2C.—Case of A. B. Fracture of graft; marked callus exudation. (Sketch from skiagram.)

FIG. 2D.—Case of A. B. The fracture of the graft united. (Sketch from skiagram.)

tion and firm union at the site of fracture. This case was a great encouragement to me, for the transplant was laid in an environment of firm cicatricial tissue. The illustrations are drawn from the x-ray photographs (Figs. 2 A, 2 B, 2 C, 2 D).

2. To Replace Defects of Bone where Portions of Bone have been blown away by Gunshot Wounds.

Treatment here follows the same lines as in the case cited.

3. To Immobilize Injuries of the Spine in Cases of Tuberculous Arthritis, or Injuries which lead to the Development of Kyphosis.

In the present war there have been many injuries of the spine which have been followed by the rapid development of a kyphos, sometimes due to traumatic osteo-arthritis, sometimes to tuberculous changes following the original injury. In either case the treatment requires prolonged rest, during which the patient is fixed in recumbency. The period of recumbency can be very materially reduced by a judicious operation.

4. As a Substitute for Plates and Screws.

Bone grafting can be used as a substitute for plates and screws in the treatment of certain types of fractures, and to assist in securing union in cases of ununited fractures.

TECHNIQUE OF BONE GRAFTING.

Pieces of bone for grafts may be taken from almost any bone in the body, but for most purposes the tibia is the most convenient quarry in which to delve, for from it pieces of bone can easily be cut of any length or thickness likely to be needed. When a curved piece of bone is required, as in surgery of the jaw, a portion of suitable shape may be found in one of the ribs. I have employed the shaft of the first metatarsal to replace a defect in the ulna. The periosteum is left behind, the required length of the shaft with the whole of the endosteum being transplanted. The shaft of the metatarsal bone is rapidly regenerated. The tibia, however, is the bone of choice, as periosteum can be transplanted with the bone.

Operation.

The first stage of the operation is to prepare the bed for the graft, freshening the bone ends. A pliable probe is then laid in the defect and bent to the exact length of the graft required. The wound is packed with gauze to stop bleeding and covered with a sterile towel while the surgeon removes the graft from the selected area.

If the tibia is chosen, an incision of suitable length is made along the outer side of the anterior border of the tibia and the tibialis anticus is partially separated from its insertion. The bent probe is then laid on the bone, and the exact length of the graft required is marked off. The periosteum is then incised on the outer and inner surfaces of the bone, completely mapping out the portion to be removed.

The removal of the graft is greatly expedited by the use of a double circular saw (Fig. 3) electrically driven. Great care must be taken to ensure that any part of the apparatus with which the surgeon or his assistant may come in contact is scrupulously sterilized.

FIG. 3.—Double circular saw for cutting bone grafts.

If an electric motor is not available a good hand motor may be used. Failing both, the graft may be cut out with drill and chisel, but this is a slower process, and requires some care to avoid splintering the graft or splitting the tibia. The method of procedure is to drill a series of holes along the line of the incision in the periosteum, and then connect these with the chisel. The drill holes should be made into the medullary canal, so as to ensure having some of the medullary aspects of the bone in the graft (Fig. 4).

The transplantation should be made immediately; the graft should be picked up with forceps and not touched even with the gloved fingers. It is laid directly into the prepared bed, in which all bleeding has stopped by this time. I am convinced that it is a mistake to wash the graft in saline lotion or leave it in saline while something else is being done. The best results follow immediate closure of the deep tissues round it and suture of the surface wound. The limb must then be securely controlled in correct position either by splints or by a plaster-of-Paris case.

FIG. 4.—Sliding graft marked out by drill holes preparatory to cutting out with chisel.

SPINAL FIXATION.

Two operations are generally described for spinal fixation—*Albee's* and *Hibb's*. The details of the operations ought to be pretty well known, as they have been before the profession for several years.

FIG. 5.—Bone transplanted into cleft made in spinous processes (Albee's method).

Albee's Operation.

This operation consists in transplanting a slip of the tibia into a series of spines of vertebrae, bridging the weak spot in the vertebral column (Fig. 5).

The surgeon should begin by preparing the site for the graft. Each spine, including two above and two below the weak or diseased vertebra or vertebrae, is split and broken outwards (Fig. 6), the junction of spine and lamella being also roughened. The bed is packed with gauze to stop bleeding.

The graft from the tibia is then cut with the circular saw, or chisel and drill. The front of the tibia is reached by securing the heel against the buttock with the knee in acute flexion. This enables the surgeon to cut the graft without turning the patient over. The whole operation can thus be performed quietly and expeditiously.

The graft is then transferred and implanted while an assistant stitches the wound in the leg.

No difficulty has been experienced in nursing these cases on their backs in a Thomas's frame. This is applied most easily after these operations by laying the frame face downwards over the patient and turning the patient and splint together with the aid of a sheet, thus avoiding any strain upon the implant.

FIG. 6.—Diagram of split spinous process with graft inserted in cleft.

Hibb's Operation.

In this operation bony fixation of the spines is obtained without transplanting bone from the tibia. The spines are split, the upper and lower margins are broken away towards the adjacent spine, so that the fragments split away from one spine interlock with those split from the next. The laminae can also be ankylosed. Superfluous chips of bone are sprinkled along the site of the operation, so that a line of callus is formed locking all the spines together. I often prefer to lay the graft upon the laminae rather than between the spinous processes. A very suitable bed can be prepared there upon which the transplanted bone easily lies (Fig. 7).

These operations are particularly useful in cases in which the vertebrae affected are in the lower dorsal or lumbar regions, for it is difficult to control these areas completely in a support or jacket in which the patient can go about. The alternative is prolonged recumbency fixed in a splint or Thomas's frame. The result of one or other of these operations is that a patient who in former days would have been kept fixed in recumbency for a year or more can be allowed up in a light spinal support in three months, and can go about his ordinary business as soon as he can walk comfortably, for with this osseous bond between the vertebrae there is practically no fear of kyphotic deformity occurring.

FIG. 7.—Bone graft laid upon the laminae.

TECHNIQUE OF BONE GRAFTING FOR FRACTURES AND DEFECTS IN CONTINUITY.

The technique of bone grafting for fractures and for the replacing of defects in continuity of long bones, either from loss of bone or from non-union, follows very similar lines.

My views on the use of plates and screws in the immediate treatment of fractures have been stated before, and need not be repeated at length. In most parts of the limbs good alignment and good functional results can be obtained by simple reduction and setting in appropriate splints, and therefore the routine use of plates seems superfluous. The art of setting fractures is deserving of more study than has been given to it by many members of our profession in recent years. In the long bones correct alignment of the limbs, and therefore of the lines of action of muscles and joints, is more important than faultless apposition of the ends of the fractured bone.

Excellent as plates and screws are in certain emergencies, experienced surgeons know that they produce actual delay in true and efficient osseous union of the fracture.

In any case a metallic plate is a foreign body, and the

inevitable tendency of the tissues is to encapsule or encyst the foreign body, while transplanted bone can be built into the structure of the part, and therefore assists osteogenesis.

Bone Grafting for Recent Fracture.

In my experience, spiral fracture of both bones of the leg, especially in the lower third, is the only fracture in the limbs which regularly presents almost insuperable difficulties to satisfactory reduction and setting by non-operative means. The difficulty is not in reducing the fracture, but in persuading the fragments to stay in correct alignment. The cause lies in the great tendency of the foot and lower fragment to rotate, and then the fragments override.

The Sliding Inlay Method (Albee).

In this fracture the sliding inlay of bone, described in a previous article (BRITISH MEDICAL JOURNAL, 1916, vol. i, p. 810), is a very fascinating and simple way of locking the two fragments so that they do not easily disengage when they undergo slight rotatory movements. All that is required is the parallel circular saw shown in Fig. 3.

The fracture is reduced and held or clamped in position while the cuts are made as in the diagram (Fig. 8, A and B).

FIG. 8.—A, Inlay slide before being placed in position. B, Inlay graft placed in position.

The shorter piece is lifted out and then the longer piece with the medulla is slipped down to lock the two fragments of the broken bone. The smaller fragment is then laid into the gap above the longer fragment which has been slid down. Muscles, periosteum, or any other of the deep tissue belonging to the part are stitched over the graft, the wound is closed and the fracture put up in sheet-iron splints or plaster, taking care that no displacement occurs. In a few days organization has occurred sufficient to prevent any further danger of displacement unless there is carelessness or some unusual disturbance of the part.

It is seldom necessary to peg or screw the fragments, and the introduction of a foreign body is to be avoided.

This spiral fracture of the tibia in the lower third of the leg is practically the only ordinary fracture for which, in my opinion, operation should be considered at once as an immediate procedure, and then fixation by bone to prevent rotation is preferable to plating if it can be done. Failing facilities for a proper fixation by bone, plating comes next.

Neither plating nor bony fixation seems necessary in any other ordinary fracture of the limbs. In the case of unusual fractures exceptions occur. Further, each surgeon must, of course, use his own judgement in every case that comes under his notice, and employ those methods which he best understands and in which he feels most confidence. These will differ according to the surgeon's training. My contention is, however, that a surgeon skilled in the use of splints can get good results so generally that operation is rarely needed.

Ununited Fractures.

It may be admitted that in dealing with ununited fractures when firm fixation is required, plates and screws afford a most secure and rapid means of fixing the fragments. This method requires less surgical skill than when bone grafts are used, both in the operative procedure and the after-treatment. There is, however, always the point to be considered that in these cases the patient has already shown defective osteogenetic power at the seat of fracture, and the plate is, after all, a foreign body, which will be likely to impede osteogenesis, while a bone graft is a direct assistance to osteogenesis.

Method of Dealing with Ununited Fracture.

For many years I used to cut down on the ununited fracture, crush and drill the ends of the bones to open up new routes for fresh blood vessels, and turn a strip of periosteum off one fragment down to the other.

At a later period I employed in addition animal bone as a graft, with results which were not very encouraging. The use of a strip of the fractured bone as a bridge

FIG. 9A.—Fashioning of bed and freshening of ends for a slide graft in an ununited fracture.

FIG. 9B.—The slide in position; portion removed from bed distributed between ends of bone.

between the two fragments was followed by much better results. (Figs. 9A and 9B.)

It is assumed in the methods now to be described that autogenous grafts are always used. The three methods of employing a graft have been referred to in a previous article.

1. The Lateral Graft.

This consists of laying a strip of bone along the side of the bone to be repaired, taking care to make a fresh bed for the graft along its whole length, so that raw bone is in contact with raw bone (Fig. 10).

It is the simplest method, and often the only one which can be used—for example, when the ends of the broken bone are tapering and wasted (Fig. 11, A, B, C).

FIG. 10.—Lateral graft.

2. The Intramedullary Plug (Fig. 1).

This can only be employed when a good open medullary canal is available and the transplanted bone can be inserted into the medulla above and below the fracture. This is often difficult. It is advisable, when possible, to

FIG. 11.—A, Preparing bed for transplanted lateral graft. B, Transplanted lateral graft held in position by catgut. C, Transplanted lateral graft held in position by nails.

use it in combination with the sliding or the lateral grafts.

3. The Sliding Inlay.

The inlay method described above can be employed when bridging a gap; the bits of bone cut from the end of

FIG. 12.—The intramedullary plug used in combination with the sliding or lateral graft.

the slide must not be wasted, but should be broken up and sown along the site of the defect to form additional foci of osteogenesis.

A combination of the sliding inlay (Figs. 9A and 9B) and medullary plug is a strong and satisfactory method when available (Fig. 12).

CONCLUSION.

Recapitulating in brief, it may be said that, whatever particular theory of osteogenesis may be the true one, the following points have proved valuable in practice:

The area of the graft must be kept scrupulously aseptic, and free from unnecessary blood clot. Adequate blood supply is necessary to the growth of the graft.

The graft must be placed in close apposition to raw surfaces of the bone with which it is to unite.

The whole region must be kept fixed for a long period for undisturbed organization to take place.

The bone graft should be autogenous, and it is better that it should include both periosteum and medulla wherever this is possible, for both these aspects of the bone afford facilities for the growth of new blood vessels.

Surgeons should have patience, for union is often delayed, and hasty conclusions that union is not going to take place, and consequent relaxation of strict fixation of the part, may convert a case of delayed union into one of non-union.

After any of these procedures it is essential to fix the limb absolutely to let new vessels grow undisturbed by chance movements, for the idea of the operation is that all the transplanted bits of bone shall become vascularized.

As a general rule, the limb should be kept fixed and undisturbed for at least twice the time necessary for union of the same bone in an ordinary simple fracture.

I often see cases which have been operated on, often plated, by some other surgeon, in which splints have been removed at the end of a few weeks, and the case has been regarded as a failure because union has not taken place.

There is no definite time within which a fracture will unite. The times given in textbooks are understated as applied to the majority of cases. For example, I may quote the case of a patient, seen in 1908, with an ununited fracture of the humerus of twelve months' duration, which was treated by the "hammer and dam" method, but had to be kept still for nearly six months before the bones united. The ultimate union was absolutely satisfactory. Operative procedures had previously failed. This question of the consolidation of fractures has been discussed in a previous paper. The wounds received in this war have brought the surgery of septic bones very much into the foreground, and bone grafting will have to be very extensively practised. We must be careful to allow a sufficient time to elapse before proceeding to this operation. It is difficult to formulate an exact rule as to when the operation should be performed, for we seem never to be quite free from the danger of recrudescence of sepsis. My habit is to wait for at least six months after a sinus is closed, during which time and for a variable period afterwards efforts can be made to improve the general nutrition of the limb. It frequently happens that during this delay union of the fragments takes place, and no transplantation is needed. Early operation is to be discouraged from every point of view, and failure to observe this fact has resulted in many a tragedy. It is very exceptional, unless there has been a great loss of bone, for non-union to persist in fractures which are the seat of the type of suppuration met with at this time.

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SUTTON, of Kansas City, relates in the *Journal of the American Medical Association*, January 15th, the case of a girl of 18, a stenographer, intelligent, mentally alert, and with no stigmata of degeneration, who acquired a habit of twisting the eyelashes and the hair of the eyebrows and scalp, and breaking them off short with the edge of the thumb and forefinger a little above the surface of the skin. She did not pluck out the hairs as in "trichotillomania" or *tic de l'épilation*. The result was the appearance of bald patches on the scalp with short stumps of healthy hair, whilst the hairs around were perfectly normal. The baldness was noted by the patient's friends when she was sixteen. When worried or idle she would gaze into space for hours at a time and twist and snap her hair, throwing away one hair after another, but it was only when under treatment that she admitted that the baldness was artificial. When a child she sucked her fingers and bit her nails. Under a course of psychotherapy the patient's condition greatly improved within a few weeks.

ON THE LIFE-HISTORY OF ASCARIS LUMBRICOIDES.

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Preliminary Note.

The development of *Ascaris lumbricoides* is at present almost universally considered to be direct. It is well known that the eggs passed in the faeces of man undergo development in the outer world up to the formation of a motile vermiform embryo. The egg containing this embryo may readily reach the alimentary canal of man, and it is supposed that it there hatches, and that the larva, having escaped, develops in this site into the adult. This theory is based on the work of Davaine,¹ Grassi,² Calandruccio,³ Lutz,⁴ Epstein,⁵ Jammes and Martin,⁶ Martin,¹¹ and Wharton.¹² I have not at present access to the works of these authors in the original with the exception of the articles of Jammes and Martin and of Wharton. Summaries sufficient for the present purpose are, however, available in the textbooks of Leukart⁴ as regards Davaine, of Railliet,¹³ Manson,¹⁴ Clifford Allbutt,¹⁵ and Castellani,¹⁶ as regards the later writers.

Davaine administered ripe eggs to rats, and found that after twelve hours free live larvae were to be found in the lower part of the small intestine. He also introduced ripe and unripe eggs in glass capsules closed with linen into the alimentary canal of the dog and found that after the lapse of a certain period the ripe eggs had disappeared, whereas the unripe eggs remained. He concluded that hatching and development occurred in the alimentary canal of the definitive host.

Grassi administered ripe eggs to himself, and two months later found eggs in his stools. Calandruccio infected a child of 10 which had previously suffered from worms, but had been relieved of these parasites by anthelmintics. Lutz fed an adult on ripe eggs, and found evidence of the subsequent appearance of adult worms. Epstein's work is unfortunately not available even in summary, but from the context of the references it is clear that he successfully infected man.

Jammes and Martin worked on the line of experimental hatching of ripe eggs in artificial and natural solutions, and found that hatching took place readily and *en masse* in 0.8 per cent. salt solution (which they consider to be an alkaline solution) at 37° to 40° C. Martin found that the embryos of the ascarids from the calf, pig, horse and dog hatched best in alkaline solutions, and that when developed eggs were introduced into the alimentary canal of an animal they passed through the stomach unaffected and only hatched after they had been subjected to the action of the alkaline juices of the intestine (Ext. quoted from Wharton).

Wharton states that direct infection can take place, but that the embryos must be "completely developed." He does not give the period necessary to secure this complete development.

In spite of the general acceptance of the theory there is a considerable bulk of evidence against it.

Davaine¹ administered three to four hundred ripe eggs to an ox—an animal which is stated to harbour *Ascaris lumbricoides*—and found that after four months no worms were present in the intestine. Küchenmeister² experimented with a dog, which, however, escaped from his observation. Leukart⁴ fed a rabbit on ripe eggs, and found no worms after ten days; a dog was also treated, and was equally unresponsive after fourteen days. This very experienced helminthologist also fed a pig for three weeks on several thousand ripe eggs, and did not find any worms on section. An experiment on man was arranged in 1857, but it is not clear that it was carried out. He also administered to a horse the eggs of *Ascaris megalocephala*; to a dog those of *Ascaris marginata*; to a cat those of *Ascaris mystax*, with invariably negative results.

Leukart, therefore, maintained that the life-history of *Ascaris lumbricoides* would be found to be completed by an alternation of hosts. He supported this opinion by the facts known with regard to (1) *Ascaris acus*, which is found as an encysted larva in *Leuciscus alburnus*, and in the