THE REPAIR OF WOUNDS

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Soon after an injury, involving damage to or loss of tissue, is inflicted, reaction sets in which may be considered as preliminary to repair.

The repair of wounds and injuries may therefore be said to take place in two stages. The first stage, or stage of reaction, has for its object the cleaning up of the wound and the removal of all the dead and damaged tissue resulting from the injury. The second stage, or stage of repair proper, has for its object the reconstruction of the organism, and as far as it is possible the 'restitutio ad integrum'.

Reaction is essentially a vascular phenomenon, and it occurs only in vascular tissues. The circulation in the capillaries immediately adjacent to the site of injury is slowed down and then stopped, plasma escapes into the interstitial tissue and leucocytes move out through the wall and proceed towards the injured parts. Thus two zones are formed, the zone of *stasis* in which the circulation is stopped, which immediately adjoins the area of necrosis, and which in the human being is irreversible, and the zone of *prestasis*, where the movement of blood in the capillaries is slowed down and which is reversible.

Outside the zones of stasis and prestasis there is a third zone of variable depth, the zone of *inflammatory hyperaemia* where the arterioles and capillaries are dilated and the current of blood is accelerated. The inflammatory hyperaemia ensures a free blood supply to the reacting tissues.

The fixed tissue cells in the area immediately adjoining the damaged part react by returning to the embryonic state and beginning to profilerate. They give rise to *fibroblasts* which acquire the property of forming collagen, and to large cells called *histiocytes*, which are endowed with phagocytic powers and which play an important part in the disintegration and removal of dead tissue elements.

The origin of the fibroblasts is not definitely established. Available evidence points to their being derived from the fixed tissue cells which, under the influence of some substance or *evocator* formed locally, return to the embryonic state and re-acquire the property of forming collagen fibres. Whether all the fixed tissue cells are capable of being thus activated, or whether this property is confined to a certain number of cells which lie dormant in the tissues until they are awakened as the result of injury, is not yet settled.

The capillary endothelium proliferates and forms buds. These become canalised and transformed into new capillary loops, which advance towards the injury or loss of substance carrying with them fibroblasts and histiocytes. This tissue consisting mainly of newly formed capillary loops, fibroblasts, histiocytes, covered by a layer of leucocytes is called *granulation tissue.*

Granulation tissue.

The granulation tissue grows into and replaces the damaged and mucosed part or fills up the gap left by any loss of substance.

Granulation tissue undergoes further changes. The fibroblasts soon begin to lay down collagen fibres as a felted mass. The young fibrous tissue contracts and in doing so approximates the edges of the gap, and closes the cavity. The blood vessels are compressed and they gradually disappear. The result is an almost avascular scar.

The Time Factor.

In a simple uncomplicated wound, the process of mopping up dead tissue cells and debris usually occupies about three days. On

the fourth day granulation tissue is well formed and fibroblasts can be made out in considerable numbers, and the healing wound begins to show some resistance to disruption. The period during which the healing wound can easily be pulled apart is referred to as the *lag period*. After this lag period, which is normally of about four days duration, the tensile strength of the wound increases rapidly up to the tenth day, when the rate slows down until healing is complete.

Factors which Influence Healing.

If the force required to disrupt a healing wound is plotted against the time measured in days or hours, an S-shaped curve is obtained.

An adequate blood supply is essential for the processes of repair. Without it, repair is slowed down in all its stages and even stopped altogether.

During the growing period the processes of repair are accelerated, the lag period is reduced by as much as one day, whilst the rise in tensile strength occurs at a more rapid rate. In old age the reverse takes place and the processes are slowed down.

Other factors which prolong the lag period and slow down the repair processes are :

(a) General ill-health.

(b) Deficient protein reserves.

(c) Deficiency of ascorbic acid.

(a) General ill-health requires no comment.

(b) Deficiency of protein reserves is a condition, which though obvious, has only been given its due importance in recent times. It is noticed that, during the healing of wounds the N-balance in the urine becomes negative, indicating that more proteins are being broken down than are being assimilated. It appears as if the body, in order to obtain the materials for repair, rapidly breaks down protein using up only a small moiety, and eliminating the rest. It appears further that the processes of regeneration have a priority over the maintenance needs of the body. Thus the Salamander will reform its tail, even if starved of food, by utilising its own body tissues; in this way also may be explained the rapid wasting in cases of extensive wounds. Further in Malta, during the seige, the healing of wounds occured normally even though the diet was very near the indispensable minimum. The extra protein is obtained by using up the protein reserves. If these are not available, or when these are exhausted, life becomes impossible.

(c) Ascorbic acid is necessary for the formation of collagen fibres. Its deficiency makes the tensile strength of the healing wound rise at a slower rate, or not at all.

Mechanical Factors which Influence Repair.

Sufficient rest is essential for the process of repair to proceed normally. Nature secures the necessary rest and immobilisation, by providing the pain mechanism, with its attendant inhibition of movements, by providing reflex muscular contracture, which immobilises the part, and even in some instances by providing temporary means of retention such as callus in the case of fractures.

Art has improved on the efforts of nature in this respect and immobilisation by suitable means such as dressings, splints or plaster, is regarded as indispensable in the treatment of injuries. It is recognised that if the parts are not kept sufficiently at rest, repeated injuries interrupt the orderly processes of repair by producing small haemorrhages or foci of necrosis which make the healing process go back to its starting point.

Infection.

The presence of infection delays the processes of repair. Infection causes further necrosis of tissue which sometimes outstrips repair. When this happens the wound enlarges instead of healing. When infection causes as much destruction as the natural processes of repair are just able to cope with, the wound remains in 'statu quo'.

Scar Tissue.

Healing processes as described, occur in vascular mesenchymal tissues.

In areolar tissue the defect is bridged over by scar tissue, a tissue consisting of a felted mass of collagen fibres which has the property of contracting and strangling its own blood supply. Scar tissue, therefore, is almost avascular, and thus has very limited powers of reaction or regeneration which may be summed up in the statement that scar tissue has no healing powers; when subjected to injury it breaks down and disintegrates.

During operative procedures, scar tissue is removed as far as possible, so that the margins of the operative defect consist of healthy vascular structures. On the other hand, its property of disintegrating when subjected to injury such as stretching, is made use of in dilating fibrous structures by stretching with appropriate instruments. Its property of contracting appears to be inhibited as soon as the young scar tissue is covered with epithelium. For this reason it has become the practice to provide a covering of epithelium to raw granulating surfaces, as early as possible, by means of skin grafting. In this way the formation of excessive scar tissue is prevented and deformities resulting from its contraction are avoided.

Repair in Special Tissues.

In some tissues, notably in aponeuroses, tendons and bone, repair goes a step further. Not only are the ends of the defect joined together, but the original tissue is actually reconstructed.

In membranes covered with endothelium, there is a strong tendency for the scar to be subsequently removed and for the original structure to be regenerated. It is well known that adhesions in the abdomen tend to disappear. The dura mater, in a comparatively short time, is able to regenerate both the fibrous and the endothelial layer lining the subdural space.

In tendons, the gap is bridged at first by granulation tissue, but soon the fibroblasts and histiocytes show a tendency to arrange themselves parallel to the lines of tension, and collagen fibres are laid down along these lines, parallel to one another. In this way the original structure of the tendon is reproduced. In such a process the cells of the paratenon and those lining the tendon sheath play an important part in supplying the fibroblasts and the histiocytes.

In bone, the processes of repair are still more complicated. When a fracture occurs, the gap between the fragments is filled up with blood which constitutes the haematoma. The haematoma surrounds both ends of the broken bone and the sides are bounded by the soft tissues of the part. The first stage of repair consists in the formation of granulation tissue, which advances into and replaces the haematoma. Some of the activated mesenchymal cells, which accompany the newly formed capillaries, have the property of producing ossein, an organic substance capable of becoming permeated by lime salts. As soon as the inflammatory hyperaemia, which has led to the decalcification of the ends of the bone, begins to subside, this matrix becomes infiltrated with lime salts and spicules of bone are formed, which pervade the organising granulation tissue and give it increased consistence. This is the *temporary callus*.

The temporary callus surrounds the ends of the bone and bridges the gap between the fragments. Its object is the immobilisation of the fracture in order to allow definitive repair to take place.

The repair process, however, does not stop here, since the cells derived from the osteoblastic tissue of bone and periosteum have the power not only of laying down bony matrix, but also of demolishing and removing it. After the temporary callus which has an irregular structure is formed, the osteoblasts along lines of stress are stimulated to arrange themselves regularly according to a definite pattern and to lay down bone according to the regular architecture of the bone in that situation; the osteoblasts

in the region outside the lines of stress, take on osteolytic properties and demolish the redundant osteoid tissue. In this manner the callus is gradually reconstructed and the original structure of the bone reproduced. The excess of callus which, now that the bone has united serves no further purpose, is removed.

Practical Applications.

(1) The knowledge of the rate of increase in tensile strength regulates the time for removing sutures.

As a rule the normal skin is sufficiently healed in 7 to 10 days to allow sutures to be removed; but in patients suffering from diseases of the digestive tract, from Carcinoma, from inanition or old standing disease, when the protein reserves are presumed to be at a low ebb, the sutures are left in for at least 14 days.

In the face and neck where the blood supply of Vitamin C and also other vitamins earlier e.g. on the 5th or 6th day.

(2) Before undertaking serious operations the blood proteins are estimated and if found deficient are brought up to standard by suitable means. In urgent cases blood transfusion proves to be highly effective. The same applies to the amount of haemoglobin in the circulating blood.

(3) After serious operations the patient is given high protein diet, and if his digestive system is unable to cope with it, blood or plasma transfusion is indicated.

(4) For the same reasons an adequate supply is very free sutures may be removed should be maintained.

(5) The importance of immobilisation for promoting rapid repair has been known for a long time, but it is continually being rediscovered and is now an integral part in the treatment of the soft tissues.