LECTURES ON INJURIES TO THE EPIPHYSES AND THEIR RESULTS.

Delivered at the Royal College of Surgeons.

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LECTURE I.

THAT the rarity of the occurrence of injuries to the epiphyses of the long bones has been exaggerated by some writers may be judged from the fact that this review is based upon the collected records of about 350 cases, excluding many doubtful and ill-reported ones. Of the total number nearly 150 have not previously been published, and I am greatly indebted to my senior colleagues at the London Hospital for the opportunity of observing and recording many of these.¹

SEPARATION OF THE EPIPHYSES.

The following points make this accident worthy of special study: (1) The possibility of more or less complete arrest of growth in the injured bone; (2) the frequent errors of diagnosis which separation of certain epiphyses have caused, errors often perhaps due to the insufficient and inexact teaching on the subject in the standard works on surgery; (3) complete separation of an epiphysis is almost invariably accompanied by stripping of periosteum from a large area of the shaft, much more than is met with in simple fracture; hence arises a somewhat greater tendency for such injuries to be followed by suppurative and necrosis, and still more to the formation, during repair, of an excessive amount of callus; it will be understood how prejudicial this may be to the movements of the joints concerned—for example, in the case of the lower epiphysis of the humerus; (4) in many cases detachment of an epiphysis implies at the same time an injury to the joint which it helps to form, a point of interest as regards both prognosis and treatment; (5) in detachment of certain epiphyses—for example, the lower femoral one and the upper one of the humerus, unusual difficulty may be experienced in obtaining reduction and keeping the bone in good position, difficulties comparatively rarely met with in the case of fracture of the shafts.

THE EPIPHYSIAL DISCS.

In speaking of the layer of modified cartilage cells which connects the epiphysis to the shaft, I think the best term to use is that of "epiphysial disc," exactly corresponding to the German "*Epiphysenknorpelscheibe*," but fortunately briefer and more euphonic. Microscopically its anatomy may be here illustrated by a specimen taken from one of the experiments which I performed on animals.

¹ EXPERIMENT I.—Rabbit, aged about 3 months, anaesthetised, and lower epiphysis of femur detached by direct hand pressure and lateral movement of the leg. The animal was then killed, and after suitable decalcification sections were obtained, which are illustrated in the drawing. The epiphysis was fully ossified, and from the bony edge a direct continuity of tissue can be traced to the trabeculae of the epiphysial disc; these trabeculae are widest and strongest towards the epiphysis, hence in cases of detachment the disc will almost invariably remain with the epiphysis. Further, it may be noted that the cells of the disc are arranged in regular columns between the trabeculae; towards the epiphysis they are small, flattened, and closely packed one on each other, towards the diaphysis they are larger and round or oval.

I have made a number of observations on the cadaver, but do not think it necessary to allude to them in these lectures except in so far as they help to clear up disputed or doubtful points. With regard to some epiphysial separations, for instance, the lower radial one, we have such abundant evidence from actual cases that *post-mortem* experiments would be needless. With regard to others, such as the upper epiphyses of the femur, these experiments have been most useful. They have shown, for instance, that by strong abduction of the limb it is quite possible to detach the epiphysis of the femoral head in young infants. They prove,

also the occurrence at nearly every site of epiphysial separation without rent of the periosteum; in fact we may say that the latter is probably the strongest means of union between the shaft and epiphyses. Thus, after the periosteum opposite the epiphysial disc has been carefully divided all round, a weight will suffice to detach the epiphysis one-fifth that required under other circumstances.

Fig. 1.—Vertical section through part of the epiphysis, the lower limit of the figure showing the edge of the epiphysial disc at which separation has taken place. The columns of cells in the disc are indicated, and the supporting trabeculae between them appear as fine black lines.

One by-result of the observation on the *post-mortem* table was to show that the exact dates given for the ossification and fusion of the various epiphyses are not infrequently deviated from. We must expect the chronometer of life to be sometimes fast and sometimes slow.

Having regard to the delicate structure of the epiphysial disc, one might expect that either the violence necessary to detach the epiphysis or the reaction attending subsequent bony union would always suffice to obliterate it and to check further growth. This, fortunately, is not the case; indeed, the epiphysial disc shows a remarkable power of resistance. Thus, in several experiments on rabbits, I found that after the lower epiphysis of the femur had been completely detached and then fixed in position by a steel peg or by other means growth continued in a normal manner. Further, when the animal had been killed a considerable time afterwards, the bone decalcified and microscopic sections made, the disc was found to be unaltered except just where the peg traversed it. The same held true when the end of the diaphysis had been excised, though here of course there was always some shortening. Ollier's experiments confirm this strength of resistance on the part of the epiphysial disc. Were it not so we may point out that Ogston's operation for genu valgum would have fallen into discredit much sooner than really happened. It will be remembered that in this operation the epiphysial disc is cut across somewhat obliquely and the two halves separated. Nevertheless, occasionally arrest of growth did occur, as the following case proves: A child aged $3\frac{1}{2}$ underwent Ogston's operation on one femur in the London Hospital. No signs of inflammation followed, and the immediate result was most satisfactory, but a limp slowly developed, and when I examined the case at the age of 10 years there was shortening in the femur to the extent of quite 2 inches. Before adult life was attained this shortening would probably amount to 4 or 5 inches.

I have been able to follow up six cases of undoubted separation of the lower epiphysis of the radius for a considerable time after the accident, in only one (in which some backward tilting persisted) was there decided shortening.² Many specimens could be adduced showing that in spite of old fractures close to the epiphysial discs of various bones, sometimes even accompanied by vertical splits of the epiphysis, the disc itself has remained unimpaired. On the other hand, it must be admitted that arrest of growth is a fairly frequent result of detachment of the epiphysis. We may consider it as almost inevitable if the latter remains displaced and only

connected by the periosteal new bone to the diaphysis. One

Fig. 2.—The upper drawing shows the diaphysis displaced and allowed to remain so. At the end of eight days it was impossible by ordinary force to replace the bone. The epiphysal disc was undergoing atrophy. The lower drawing shows the result one month after separation of the lower femoral epiphysis and erosion of the epiphysal disc. Good union has occurred, and there are still traces of the disc. The section traverses an ivory peg used for fixation.

or two of my experiments on rabbits proved that under such conditions the disc very rapidly underwent atrophy, and even when the detachment has been unattended by decided displacement or when the latter has been completely overcome, we know that arrest of growth sometimes occurs. Mr. Bryant has called attention to this in the case of the lower epiphysis of the tibia, when originally the accident has been diagnosed and treated merely as a sprain of the ankle. We may suggest that such a result is due to the subject being encouraged to walk before union has occurred, and to the prejudicial action of the body weight stimulating the disc to premature fusion. The same author has published some interesting examples of complete arrest of growth following injury to the upper epiphysis of the humerus. The differing importance of the various epiphysal discs as regards growth is well known, and will be alluded to later.

ARREST OF GROWTH.

Arrest of growth after epiphysal injury is, perhaps, most prejudicial when it affects only one of the bones of either forearm or leg. Then the companion bone—usually the fibula or ulna—will continue to grow, will push the foot or hand over to the opposite side, and distort the ankle or wrist-joint. I could quote at least eight examples of this occurrence in each situation. Some of these have called for surgical interference.

In a recent case of epiphysal separation with displacement the prompt and accurate reposition of the displaced bone, the careful avoidance of rough manipulation in so doing (much aided by the use of an anæsthetic) and the employment of cold applications to check inflammation are incumbent upon the surgeon. Whether he should warn the patient's friends of the risk of shortening is a question of medical ethics too delicate for me to attempt to answer. There is little doubt that in certain cases of injury to the epiphyses during the first year or two of life arrest of growth at the affected disc is followed by more or less impairment of development in the whole limb. Sometimes comparative disuse of the limb may fairly be given as the explanation, as in the case of excision of the knee (including a large part of the femur and tibia) recorded by Mr. Pemberton. The operation had been performed at the age of 12; six years later the whole limb was

6 inches short, and the foot $1\frac{1}{2}$ inch shorter than the opposite one.

The main difficulty met with in reduction of separated epiphyses is generally due to the interposition of soft parts, and especially of the sleeve of periosteum through which the expanding diaphysal end has been thrust. Occasionally, as in the case of the lower epiphysis of the radius, one or more tendons have become locked between it and the shaft, entirely preventing reduction.

It is most important to effect reduction as soon as possible for the following reasons: 1. The rapid occurrence of swelling will make the diagnosis and correction of the exact displacement more difficult. 2. The connecting bridge of periosteum quickly thickens and shortens; from this cause, at the *post-mortem* examination of a rabbit whose lower epiphysis of the femur I had detached and allowed to remain displaced, I found it quite impossible by any reasonable force to effect reduction, although only eight days had elapsed since the experiment. 3. The more prompt the replacement, the less will be the risk of exuberant callus, of interference with growth, and possibly also of suppuration and necrosis.

The stripping of periosteum from the shaft which occurs with displacement of the epiphyses is sometimes extraordinary in extent. Thus, in connection with traumatic detachment of both the lower and upper epiphyses of the humerus the periosteum has been found to be loosened from the shaft as far as the insertion of the deltoid. Some authorities have attached much importance to this extensive periosteal stripping as the chief factor in determining suppuration. But some apparently insoluble problems meet us here. Why should detachment of certain epiphyses be more often followed by suppuration than that of others? For example, amongst the twenty-four cases of detachment of the lower humeral epiphysis (not complicated by wound) suppuration did not once occur; out of the ten cases in which the great trochanter was concerned, it followed in six. Again, one or two cases are on record in which several epiphyses were separated at the same time, and round only one did an abscess form. When, after a severe injury to the hip or knee-joint of a young adult, suppuration comes on, and it is ultimately proved that the epiphysis was completely separated at the time of operation or death, who can decide whether the detachment followed the suppurative process or *vice versa*?

The more important any one epiphysal disc is as regards the growth of the bone—in other words, the more active the nutritional forces at that spot, the greater is the risk of suppuration following in non-compound cases of separation of the epiphysis. Without laying too much stress on this rule, we may instance the fairly numerous cases in which it has occurred after simple detachment of the lower epiphysis of the radius, of the femur, and of the upper epiphysis of the humerus. But how explain the great trochanter cases? Is it because direct violence has frequently played a part in the causation of the detachment, and the micrococci of suppuration have obtained access through the damaged skin?

It may incidentally be mentioned that it is an easy matter to distinguish, in a vertical section of a long bone, which is the most important epiphysal disc as regards growth, for the latter is always the broadest and most defined in its borders.

It is a matter of importance to distinguish between traumatic suppurative epiphysitis and acute multiple periostitis, for the gravity of the latter disease is much the most pronounced. The essential difference consists in the former showing no tendency to involve other bones than the one injured. Nevertheless, the prognosis is serious enough in the case of acute epiphysitis of a single bone, owing to the possible sequence of pyæmia, of necrosis, or of the suppuration spreading to the neighbouring articulation. It is worth while noting that in only one of my experiments on animals (fifteen in number) did any suppuration occur, although the injuries were generally made compound. The wounds invariably healed by first intention, and in the one suppurating case the pus was very small in amount, and practically confined to a cheesy abscess in the popliteal space. The animals were mainly rabbits born and reared in London, and of rather feeble vitality.

THE STERNAL EPIPHYSIS OF THE CLAVICLE.

We pass now to the consideration of the individual epi-

physes, commencing with one of the most anomalous in the whole body, that of the sternal end of the clavicle. For about eighteen years after birth the clavicle has no true epiphysis, merely a thin plate of cartilage, and there is never a well-marked epiphysal disc. At two years this cartilage is barely 1 mm. thick, at three years it is practically the same; after this it gradually increases, so that by the time ossification begins in it, during the seventeenth or eighteenth year, it has attained the thickness of 4 mm.—that is, less than $\frac{1}{2}$ inch. About the twenty-fifth year it finally fuses with the shaft. Looking at the short life this epiphysis enjoys and its insignificant size, two questions arise, What is the use of its separate existence, and is it conceivable that it should ever be detached from the diaphysis? Three undoubted cases of the latter occurrence are on record—one, aged 20 (M. Verchère³); one, aged 14 (Mr. Christopher Heath⁴); the third, aged 17, at the London Hospital under the care of Mr. Rivington, now recorded for the first time.

THE UPPER EPIPHYSIS OF THE HUMERUS.

Although the ossification of this epiphysis takes place by two or sometimes three nuclei, we may conveniently disregard this fact; from a surgical point of view there is but one epiphysis, which includes the head and both tuberosities. The cases in which this epiphysis is divided by violence into two parts corresponding to the separate ossific centres for the head and great tuberosity, or in which the latter is alone displaced, are so extremely rare that they may be left out of consideration.

The epiphysal line is a remarkably sinuous one, the more so the older the child grows, and the sinuosity follows the curve of the upper surface of the bone; it is best seen in vertical sections, which show that the depth of the epiphysis is rarely more than from 2 to 3 centimetres. Almost the whole of the capsular ligament is attached to the epiphysis and the following important muscles—the supraspinatus, infraspinatus, teres minor, and subscapularis. In cases of detachment, owing to these firm connections with the scapula, the epiphysis invariably remains in the glenoid cavity. There is also a tendency for the epiphysis to be abducted. The epiphysal disc is far more important than the lower one with regard to growth in length of the humerus. Fusion with the shaft usually occurs in the twenty-first year, though it is sometimes delayed until twenty-four, as a dissected case of von Bruns' demonstrates, and Uffelmann asserts that it may be postponed to the thirtieth.

In most cases of detachment, the shoulder-joint is probably not opened, and this is the more likely the younger the patient. It is sufficiently accurate, and a point of practical importance, to say that separation of this epiphysis before the age of about 20 takes the place of dislocation of the shoulder-joint.⁵ How much trouble in treatment and discredit to the practitioner might have been saved if this fact were generally admitted! Time after time the doctor called in to a case of separation of this epiphysis has pronounced it to be one of dislocation, has employed various methods of reduction, and has been mortified by the tendency to recurrence and the very indifferent result obtained. The same variety in the violence employed is met with in the two cases. Traction on the arm, as in the manoeuvres of child-birth, strong abduction, a violent wrench or twist of the humerus, a fall or blow on the shoulder, may all be responsible for separation of the epiphysis. And as in dislocation, the displacement of the diaphysis is in most cases (about 60 per cent.) inwards—towards or under the coracoid process. In the minority the diaphysis is driven forwards or outwards, whilst in some cases there is a diastasis without any displacement, the two fragments being held in apposition by the untorn periosteum. The younger the patient the more common are these cases of simple detachment without displacement—cases of extreme difficulty perhaps in diagnosis, but of great importance from the possible arrest of growth which may result. Whether muscular action alone may produce separation of the epiphysis, as it undoubtedly can dislocation of the humerus, is very doubtful.

Analysing the records of sixty-six cases of separation of this epiphysis (thirteen of which were under my own observation), I find six occurring at birth, and four during the

first year of life. Omitting these, the average age at which the detachment occurred was 13 years, in no fewer than seventeen was the patient 15 years old or more. Sufficient evidence exists from *post-mortem* examination or operation (in all, eleven cases) to enable us to say that the separation occurs in probably nearly all of the cases exactly at the epiphysal line. The strong curve of the latter, due to the upward projection of the top of the diaphysis about its centre, has already been noted, and is of practical interest. An American surgeon named Moore claimed that when the diaphysis is displaced it hitches (so to speak) against the outer and under part of the epiphysis; hence the difficulty in reduction, to be met by a manoeuvre dignified by the name of "Moore's method," which simply consists in carrying the humerus forwards and upwards, then making slight extension whilst the arm is brought down to the side, and there fixed. Moore regards this locking of diaphysis and epiphysis as of constant occurrence, and that "no plan of treatment" (except his own) "is likely to succeed." The whole contention is a fallacy. In the case of displacement of the diaphysis, here, as in other parts of the body, the main difficulty in reduction, if any exists, is due to interposition of soft parts, and especially of the tense periosteal sheath, through which the expanding end of the diaphysis has been driven.

The following are the chief points in the diagnosis of separation of this epiphysis:

1. The age of the patient—under about 20 years.
2. The arm is comparatively helpless, the elbow often directed a little outwards or backwards.
3. Abnormal mobility just below the shoulder-joint, best made out by abducting the humerus.
4. Rapid swelling about the shoulder, some shortening if the diaphysis is wholly displaced.
5. Muffled crepitus on replacement.

Dislocation is diagnosed in at least 50 per cent. of the recorded cases; a thorough examination under an anæsthetic is important. If once brought fairly back under the epiphysis the sinuous nature of the junction will tend to keep the diaphysis in place. Steady traction on the arm, slight abduction, aided by rotary movement, or by direct pressure, is the most likely to attain this end. There is probably no harm in trying "Moore's method," provided that no violent jerking movement is allowed. What should be done if the diaphysis protrudes just under the skin, and prolonged efforts at reduction fail? Here (with every precaution as to asepsis) the end of the diaphysis should be exposed, the opening in the periosteal sheath enlarged, or the rent in the other soft tissues held open, and the bone returned to place. This has been done with success even at an interval of several weeks from the accident, but it is then usually necessary to resect part of the diaphysis.⁶ The same course should be followed in the cases of compound separation, where the diaphysis protrudes through the skin. In five such cases resection of the diaphysal end was performed, and the bone returned to place, all ultimately recovering with a very useful arm. In two reduction was obtained without resection, but in one of these 2 inches of the bone subsequently necrosed.

Amongst the rarer complications we have to note injurious pressure on the axillary artery or plexus of nerves, the former in two cases—Clark's and Hamilton's—having caused gangrene of the whole arm. Suppuration is exceptional in the non-compound cases, and should rarely occur after reduction of the compound ones; but it has more than once led to the death of the patient. Noting also that bony ankylosis of the shoulder, from some cause difficult to explain, followed in four of my collected cases—in one suppuration had occurred—we come finally to the important question of arrest of growth in the humerus, and even in the whole arm (with or without paralysis), following detachment of this epiphysis. Striking examples have been published by Bryant, P. Vogt, Bruns, and Humphry. In this case, as in practically every one where the arm has been more or less paralysed and non-developed, the accident which was to blame occurred at a very early age.⁷ Whether the brachial plexus is torn as well as pressed on by the displaced diaphysis in these cases we cannot at present decide.

The necessity for thorough examination, correct diagnosis, and gentleness in manipulation in every case of detachment

of this epiphysis must be emphasised. Nothing will so certainly be followed by arrest of growth as roughly rubbing the fragments together, even if reduction is effected, and so destroying the delicate epiphysal disc of cartilage.

A very important question arises as to how far an operation is justifiable in a case where the diaphysis has remained partly or wholly displaced and the patient comes under care some weeks or months after the accident. What bad results have we to expect if nothing is done? First, arrest of growth, since the epiphysal disc almost certainly remains with the epiphysis. But the nearer the subject approaches adult age the less need we think of this; further, if by operation we replace the diaphysis it is by no means certain that we can prevent shortening occurring. Secondly, impaired movement at the shoulder-joint, especially in the direction of abduction and rotation. If these are much limited an operation is probably advisable, and still more so if there is evidence of pressure on the axillary vessels or the brachial plexus (both, however, rare). Thirdly, ankylosis of the shoulder. Much will depend on the peculiar circumstances of the case and the operative zeal of the surgeon, but the example of Bruns's two cases and of Smith's is very encouraging in the direction of operation. In one case (a recent compound one) the diaphysis was fixed in place of a steel needle (Helferich), with good result. If the diaphysis remains displaced to a considerable extent a very fair result may in many cases be expected (although shortening will probably occur—this is shown in the cases recorded by Puzey, Hamilton (two), and in one of my own. In all these, firm union occurred, and movements at the shoulder-joint were very good. Owing to ossification in the connecting bridge of periosteum, we have little cause to fear non-union between the diaphysis and epiphysis. However, in two cases (both occurring at birth) recorded by Bertrandi and Durocher, a false joint appears to have formed.

In recent cases, after reduction, care must be taken that the humerus be not rotated on its vertical axis, especially in the inward direction. The epiphysis tends, as already said, to be somewhat abducted, but not to be materially rotated. It is inadvisable to use a bulky axillary pad, and a neatly fitting poroplastic shoulder cap is one of the best forms of of retentive apparatus. Weight extension can but rarely be required.

REFERENCES.

¹ Time will not allow of an introduction dealing with the history and literature of the subject. It must suffice to say that during the last forty years no one has more contributed to our knowledge of injuries to the epiphyses than my father, and I should be pleased if the present work were regarded as in any way supplementary to his. Bruns, Vogt, and Bardenheuer, in Germany; Ollier, Manquat, and Salmon, in France; Bryant, Humphry, and Hamilton, amongst English writers, should be named among the chief authorities on the subject. ² Goyrand followed up three other cases; in neither did shortening result. ³ *Bulletins de la Soc. Anatomique*, 1888. ⁴ *Clinical Society*, November 10th, 1882. ⁵ Out of 207 cases of true dislocation, only two were in subjects under 20 years of age (Krönlein, Stimson). ⁶ Bruns, two cases; W. J. Smith, one case; operated on four weeks, five weeks, and two months after the accident. In all, reduction and a good result were obtained. ⁷ In Professor Humphry's case at six months; in two of Vogt's cases at birth; in Malgaigne's "at an early age."

MEDICAL STUDENTS IN GERMAN UNIVERSITIES.—According to Ascherson's *Universitäts-Kalender* just issued, the total number of students in the universities of the German empire in the current summer semester is 27,500. Of these, 8,575 are students of medicine, a falling off of 263 as compared with the corresponding semester last year.

PROFESSOR KUNDT, of Berlin, and Professor Kekulé, of Bonn, have been elected Knights of the Peace, or Civil, Class of the Prussian Ordre pour le Mérite. This distinction, which was valued even by that arch-enemy of shams, Thomas Carlyle, is reserved for men of the very first rank in science and literature.

MEDICAL EDITORS IN SPAIN.—The editors of the medical journals published in Madrid recently dined. The gentlemen taking part in this interesting Agapemone were Dr. Serret, of the *Siglo Medico*; Drs. Quintana and Aycart, of the *Revista de Sanidad Militar*; Dr. Ulecia, of the *Revista de Medicina y Cirugía*; Dr. Larra, of the *Revista de Terapeutica*; Dr. Navarro, of the *Boletín de Medicina Naval*; Dr. Pinilla, of the *Medicina Contemporanea*; Dr. Marin y Sancho, of *La Farmacia Española*; and Dr. Valledor, of the *Revista Dosimetrica*.

THE CROONIAN LECTURES ON THE PHARMACOLOGICAL ACTION AND THERAPEUTIC USES OF THE NITRITES AND ALLIED COMPOUNDS.

Delivered at the Royal College of Physicians of London.

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LECTURE II.—(Concluded).

I PASS on to the pharmacology of the nitrate group before dealing with the therapeutics of the nitrites, because the organic nitrates, about which I shall have most to say, have in some respects a similar physiological action to the nitrites, and it will be convenient to deal with their therapeutic uses together. The similarity seems to arise from the fact that under certain conditions the NO_3 molecule of organic nitrates is reduced to NO_2 , and not from any likeness in the action of the two molecules. I do not propose to do more than indicate a few points of special interest in connection with the metallic nitrates.

I have already pointed out the very marked difference in toxic influence on skeletal muscle between the groups NO_2 and NO_3 , when combined with a metal of small physiological activity like sodium. I have shown that whilst nitrite of sodium is a powerful muscle poison, the nitrate tends to preserve muscle vitality. The striking contrast between the action of these two salts can only depend on the difference between the physiological properties of the group NO_2 and NO_3 . This difference can be traced in all the metallic compounds of the two groups.

The nitroxyl ONO gives evidence of its influence in every compound into which it enters. The nitrate group ONO_2 plays a neutral part, and does not seem to interfere with the physiological activity of the metals with which it combines.

I have already shown this with regard to the sodium salts, and have only to add that in dilute solutions of the nitrates of potassium, barium, calcium, and strontium, the physiological influence of these metals on the skeletal muscles is as well seen as in the corresponding chlorides.

Dilute solutions of nitrate of sodium are as little irritating to the mucous membranes and raw surfaces as they are to muscular tissue. It is commonly thought that the nitrates of potash and soda are irritants; as a fact, however, their solutions when dilute are not more irritating than a solution of sodium chloride of corresponding strength, and their presence in water up to a certain amount prevents the irritation of mucous membranes which water itself causes.

A solution containing under 2 per cent. of either chloride or nitrate coming into contact with the Schneiderian membrane, the conjunctiva, or raw surfaces gives very little discomfort, if, however, left long in contact with a raw surface it gives rise to severe pain and a stronger solution of either salt is at once painful.

By the stomach mucous membrane a 10 per cent. solution of sodium nitrate is well borne, but if more concentrated and in considerable quantity, it may cause great irritation like other strong saline solutions.

The organic nitrates to which I shall allude are glyceryl trinitrate, $\text{C}_3\text{H}_5(\text{ONO}_2)_3$ (nitro-glycerine); ethyl nitrate, $\text{C}_2\text{H}_5\text{ONO}_2$; propyl nitrate, $\text{C}_3\text{H}_7\text{ONO}_2$; isobutyl nitrate, $\text{C}_4\text{H}_9\text{ONO}_2$; isoamyl nitrate, $\text{C}_5\text{H}_{11}\text{ONO}_2$. In these organic nitrates two effects have to be considered: (1) the actions of the compounds themselves; (2) that resulting from the products of their decomposition.

Nitro-glycerine.—I shall speak of nitro-glycerine first because