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IX.—*On the Different Tissues found in the Muscle of a Mummy.*

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(*Read 11th May*, 1887.)

Plate X.

To some it may be a matter of surprise, to others a question of utility, to have gone back amongst the dead of remote ages in search of a subject for microscopical examination, whilst on every side we are surrounded by living organisms whose structure is unknown. Yet let me venture to hope the result which I now have the honour to bring to the notice of the Fellows may justify the selection. Whatever may be the opinion entertained of this record of the examination, it must be admitted there is one point upon which the dead doth not speak, nor can the living offer more than silence, and that is whether a thousand or two thousand or more cycles have slipped away "with the years beyond the flood" since this muscle-structure possessed life. The time, however, has certainly been beyond a period in which we could fairly hope for the preservation and identification of any part of the minute organic tissues of either the muscular, vascular, or nervous systems.

It was to satisfy myself upon this point, but more especially as regards the preservation of the striated character of voluntary muscle, that the examination was undertaken. Very possibly others have previously made like researches, but the limited means at my disposal have not enabled me to discover any record of a similar examination. Should such be within the knowledge of some of the Fellows whose opportunities have been greater, it is still hoped this paper may extend our knowledge and dispose of some of the difficulties that attend such studies.

No doubt, in the present instance, much is due to the very careful way in which the preservation of the dead was carried out, for in two

EXPLANATION OF PLATE X.

Fig. 1. Fibrillæ in mummy muscle × 200.
„ 2. Remains of blood-vessels (?) in mummy muscle × 200.
„ 3. Broken blood-vessel in mummy muscle × 200.
„ 4. Delicate nerve-fibres in mummy muscle × 200.
„ 5. Ditto.
„ 6. Ditto.
(All the figures have been reduced from 400 to 200 diam.)

other examinations all trace of minute structure was lost, the tissues being so impregnated with the asphalt, pitch, or resinous gums and other materials used in the process of embalming, as to be useless under any of the methods of investigation that were adopted with success in this case.

About nineteen years ago there was handed to me a portion of a human mummy, the arm (I believe of a female), obtained before 1853 from one of the many Egyptian tombs, by a friend since deceased. A small piece was cut from one of the muscles—if I remember correctly, the triceps—which had been exposed by the removal of the various investing bands of linen, and carefully wrapped in note-paper, and put aside for a more convenient time, and thus came to be forgotten until a few weeks since. The little piece that was removed was about $1\frac{1}{4}$ in. long, pliable, and looking closely like a small tuft from an old cocoa-nut fibre mat or a dirty bit of spent tan.

A very cursory examination proved so attractive, that it was determined to no longer delay a more strict investigation. The question was how best to proceed, and in order to vary the methods the following reagents were used. The parts taken from the bit of muscle were cut from each end, also from the middle, and placed to soak in them for a fortnight:—

1. Glycerin 4 dr., glacial acetic acid 4 m.
2. Glycerin 4 dr., liquor potassæ (B. Ph.) 1 dr.
3. Glycerin 4 dr., sweet spirit of nitre 2 dr.
4. Glycerin 4 dr., saturated solution of boracic acid 1 dr.
5. Glycerin 4 dr., glac. acet. acid 4 m., and chloride zinc 6 gr.
6. Distilled water 4 dr., glac. acet. acid 2 m.
7. Saturated solution of salicylic acid.
8. Distilled water 3 parts, hydrochloric acid 1 part.
9. Distilled water 6 parts, nitric acid 1 part.
10. Distilled water 2 parts, rectified spirit 1 part.
11. Distilled water 16 parts, chloral hydrate 1 part.
12. Equal parts of this solution and rectified spirit.
13. Turpentine.
14. Chloroform.
15. A portion of the muscle was boiled for ten seconds in a little distilled water.
16. A similar piece was boiled for the same time in equal parts of distilled water and rectified spirit. These portions were allowed afterwards to soak in these fluids for three or four days. It may here be remarked that the boiling shrank the tissue very much, and rendered it tough and elastic, possibly from the gums used in the embalming process.

As several of these reagents offered no peculiar advantage, only those which proved most useful will be now mentioned.

No. 1 enabled me to separate the fibres into smaller bundles by means of needles and the dissecting Microscope, but did not allow of any perfect separation into fibrillæ.

No. 5 permitted the dissection to be carried further and to bring into view numerous fibrillæ, also a blood-vessel filled with rather coarse granular contents.

Nos. 8 and 9 allowed the compression of the fibres until they pre-

sented only a finely granular appearance, but in this could be detected numerous fine fibres of different refractive power from the rest of the substance. These delicate fibres with high powers could be traced into different planes forming a plexus.

No. 16 permitted the examination of similar fine fibres to be carried perhaps a little further.

The objects, when prepared for the purpose of examination, were temporarily mounted either in a saturated solution of potassic acetate and distilled water equal parts, or in distilled water with such portions of the reagent that remained adherent to the small portion of muscle that was selected.

In order to avoid assuming the correctness of my own interpretation of the appearances presented under the Microscope, every endeavour was made to photograph the structures, but where the delicate and the densely coloured portions were in the same field of view, it was found impossible to distinctly render the former, such as the fibrillæ and nerves, the same becoming through over-exposure too feeble to print with fair definition in the positive, before the exposure had been long enough to impress the image of the denser parts, consequently I was driven to the use of the pencil and camera lucida to portray these structures—structures which it was not in any way anticipated would be thus far found intact. The figures of plate X. have been drawn to a scale larger than the photomicrographs, or really than necessary, but this was done expressly that the parts might be more readily distinguished. A lower magnification was tried, but the result was less satisfactory, and it was more difficult to use.

The macroscopical appearances have already been alluded to. In the microscopical examination the first thing that was noticed in a large number of the portions that had been teased out by the needles was a coarse, granular striation, crossing at irregular intervals at right angles to the course of the fibres. This is shown in fig. 5 and in photograph No. 1. I have no satisfactory theory to offer to account for this peculiarity, which was evidently not directly due to the pressure of the bandages, as in many of the bits of muscle they were far too near each other for that idea, but it struck me as the process of embalming was often carried out or begun very shortly after death, that in this case it might have been before the *rigor mortis* had passed away, and that the albuminoid fluid substance of the muscle had been coagulated, and as it seems impressed or imprisoned under the rigor of the muscular structures.

The next notable appearance was the preservation of the muscular fibres, but unfortunately minus their own striation. In some of the prepared specimens, the muscular structure presented a beautiful wavy character which did not admit of perfect straightening, and in some cases where one of the needles used, a thin pointed flat one, had been pressed somewhat heavily on the fibres, these had been broken up into finer bundles and finally pressed out or broken up into their respective fibrillæ, whilst here and there in other specimens fibrillæ as fine lines could be seen stretching across from fibre to fibre of the teased-out muscle. The former only have been represented in fig. 1. An unsuccessful attempt has been made to photograph both conditions. Photographs 2 and 3.

In numerous specimens a peculiar appearance of aërolated lines was noticed, which generally followed the course of the fibres, but sometimes ran rather obliquely across them. These looked very much like long interspaces, varying slightly here and there in width, that had been filled with some fluid that had coagulated and imprisoned minute air-spaces. One specimen was photographed for part of its course which was more than double that depicted in the printed photograph No. 4. The slight swellings are visible in the part represented. Several of these aerolated spaces are also shown in the figs., especially fig. 2. They remain a puzzle to me, but they led me to search most carefully for some perfect minute vessels, and after spending much time over the slides I was rewarded by finding a small vessel charged with rather coarse granular contents lying between the fibres. It had been broken across in its course, and separated only a very short distance from it were likewise three small broken portions of the same vessel. The attempt to reproduce this by photography, photograph 5, has not been as successful as desired on account of the non-actinic colour of the structure, hence it has been figured more highly magnified, fig. 3. Whether the contents were blood constituents greatly altered by the process of embalming or perhaps by the injection of some preservative liquid is doubtful, but the appearance is sufficiently characteristic of its vascular nature. The use of immersion lenses disclosed nothing more satisfactory, as regards the granular contents, though some of the few separated granules seemed to have a kind of halo round them. Thus far the examinations proved very interesting. Two apparently different vessels or empty tubes were dissociated from the fibres by the needles, but it appears to me they cannot safely be said to belong to either the lymphatic or vascular systems, for some parts of the muscle had been invaded by a mildew growth. Curiously this mycelium had spread *across* the fibres and not in the direction of their length. These two tubes appeared too large to be the basic mycelium tubes connected with the smaller branches of what were regarded as due to a growth of *Penicillium* from the few conidia found lying amongst them. These vessels or tubes were photographed in order to furnish an idea of their appearance, and on the nature of which I do not venture to offer any definite opinion. Photograph 6.

During the examination of many of the prepared specimens, where the fibrous structures had been purposely compressed, the eye continually glimpsed minute fibres of a different refractive power from the other parts, running for a short distance in the substance of the muscle, and then lost to view. This led me to endeavour to prepare some of the specimens so that their course could be more completely followed. By very careful focusing the fibres could now be traced through different levels, although the plexus brought into view is figured in each drawing as if it occupied only one plane. Figs. 4, 5 and 6. Without much hesitation, I think these fine fibres must be regarded as nerve-fibres. They were not seen in any of the specimens as long as the muscle structure retained its fibrous appearance, but when it was softened, compressed, and had assumed a more or less finely granular character, then these delicate nerve-fibres were brought into view. The mode of preparation that gave perhaps the best results was when boiled for ten

seconds with water and rectified spirit, or when water with nitric acid had been used as the reagent. Every effort to photograph these structures failed, the brown non-actinic colour and density of the substance prevented the necessary differentiation, though perfectly visible under the Microscope with careful focusing. These fine fibres appeared in part as continuous bright lines, in part as grey lines, according to the position of the mirror. Unfortunately the stock of osmic acid was exhausted or it would have been used to try and render these fine fibres yet more apparent. Under none of the reagents used did the muscle structure afford any perfect evidence of the peculiar striation belonging to voluntary muscle, but some of the fibrillæ appeared to be made up of minute dots united in line, though how far this may have been inherent to the structure, or how far due to the general coagulation that was apparent in the highly compressed and softened muscle, is doubtful; but this much may be noticed, that the purposely softened muscle in which the nerve-fibrils were most visible, presented no trace of perfect muscular fibrillæ.

Although, correctly speaking, not belonging to the microscopical side of this interesting subject, this paper would be much more incomplete without some notice of the acknowledged methods of embalming, for the examination of a specimen kindly sent to me by Prof. Stewart of the Royal College of Surgeons proved absolutely useless, the flesh apparently having been placed in a bath of melted bitumen, or something of the kind, by which all structure was lost, and also in another specimen, for which I was indebted to the kindness of Mr. Shore, manager of the Hartley Institution, Southampton, which was somewhat brittle, and though treated with the same reagents, furnished no satisfactory results; still it is feared, even with this assistance, we shall find no sufficient clue to the method of preservation used in the present case. To enter into all the details would far exceed the limits of this paper, and the subject must, therefore, be but cursorily dealt with.

Whatever the origin of embalming, the process was perfected in Egypt. Besides the description given by Herodotus of the different methods, some instructions have been found in the Rhind papyrus. All the great cemeteries had their establishments for the reception and embalming of the dead, and it is stated that in those belonging to the necropolis of Memphis, there were always from 500 to 800 corpses passing through the different processes. Herodotus explains that the brains were removed through the nostrils, the intestines by an incision in the left side of the abdomen, which was then cleaned with palm wine, and afterwards filled with myrrh, cassia, &c., and the body steeped for many days in a solution of natron, an impure soda-salt found in the Natron Lake of the Libyan Desert in Upper Egypt. After the steeping, the body was handed to the swathers and bandaged with gummed cloths, and made ready for the coffin. The cost of the different methods is given as varying from 243*l.* to 96*l.*—the less costly method. This consisted in filling the abdomen with cedar-tree pitch or pine pitch, the body being steeped in the natron bath, the contents of the abdomen being allowed to escape or eviscerated by other means. The corpse of the poor was placed in natron for many days (70), after rinsing the abdomen with "syrmæa." Asphalt was said to be used with the more costly methods, and wax but

rarely. In some cases, it is stated, the body was immersed in melted bitumen. A species of tanning was also employed. Sometimes the viscera, after cleansing, were replaced, but more frequently embalmed separately, and placed in a vase near the mummy, the emptied abdomen being filled with chips of cedar sawdust, and a little natron. The cast linen of the household was usually kept for the bandages. The swathing was begun at the toes and fingers, then carried over the whole body in numberless bands; from 700 to 1200 yards of bandages, or strips three or four inches wide, it is written, have been unrolled from a single mummy. The mummies of Memphis are described as black and brittle, and those of the time of the Hebrews as yellow and flexible, the flesh even yielding to pressure, and the limbs capable of altered position without breaking. This flexibility is supposed to have resulted from the use of very costly injections of chemical solutions into the vessels, as the natron process largely destroyed the structures. The under bandages were dipped in spirit and applied wet. When Syrian turpentine came into use as in Thebes, the mummies were blacker than those of Memphis, both the bandages and body being greatly hardened. In later periods some of the bodies had an ashen grey appearance, others that were treated with bitumen were dark coloured and heavy. The methods described by Herodotus, Diodorus Siculus, and others, have been more or less confirmed by MM. Jomard, Royer, and Larrey, in their 'Description de l'Égypte.' The evisceration by incision is said to have been adopted for the rich. The mummies in which the cavities were filled with aromatic resinous bodies are somewhat olive coloured, with distinct features, the teeth, hair, and eyebrows remaining mostly perfect. Those in which the body had been filled with bitumen, are somewhat reddish, with a hard skin, and are not very alterable on exposure to the atmosphere, the features remaining moderately perfect. Those that have been salted do not differ much from the last, but the hair has generally dropped off, and the features are not so perfect. When the impure bitumen or pisasphalt was used internally, it was also supposed to have been used very hot, so as to impregnate all the tissues. The bodies that were only salted and dried remain less perfect, the features being destroyed, the hair removed, while the skin is hard and parchmenty. The Egyptian modes of embalming were copied by the Jews, Greeks, and Romans.*

The more perfect Jewish method was probably the one employed in preserving the mummy that furnished the muscle that has been the subject of this paper, though this must be accepted as a matter of speculation.

The appearances under the Microscope of living and recently dead muscle are not strictly alike, the latter has more opacity besides other differences. The muscle fluid, myosin, has been found to coagulate at 45° C., and the same temperature sets up rigor mortis, and at 75° C. the albuminoids become coagulated. In spite of the diligent physiological and microscopical researches that have been made in studying the complex character of living muscle, we are yet confronted by many

* For the rules and methods of embalming I am indebted to the pages of the Encyclopædia Britannica, 9th ed., the Penny Cyclopædia, and Kitto's Cyclopædia of Biblical Literature.

difficulties, and it is doubtful if the last words have yet been said in connection with its attributes and structure; hence we can hardly expect that the dead tissues of remote ages, no matter by whatever method preserved, should be found to closely correspond with the living or recently dead similar structures. We have lost the striation and its doubly refracting power, the sarcolemma and the long pointed nuclei, and how far the chemical substances, myosin, glycogen, inosit, creatin, &c., remain intact in the mummy muscle, is very doubtful. The withdrawal of moisture with the use of materials to delay tissue change we must expect will prevent any very perfect restoration as a whole of this highly delicate complex tissue. With the separation of the bundles of fibres into smaller ones, and these again into finer ones, all of which are held together by connective tissue, until we end at the fibrillæ, we must, it appears, for the present be content in our comparison of the recent muscular structure and the remote dead. To have gained this much with the addition of vessels and nerves, was worth the inquiry.

Note.—Since the foregoing was read, one of the Members of the Council, Mr. Julien Deby, has drawn my attention to a paper by Czermak,* published in 1852, containing the result of his examination of two Egyptian mummies, and having most kindly placed the article at my service, I am enabled to add this very brief summary of the interesting details of the microscopical examination. The mummies were those of an adult female and of a lad about 15 years of age, and dating from a period of 2000 years since; the former being in a very marked state of preservation, having been most carefully prepared and wrapped with about 4000 yards of bandages, though not a person of an exalted station. The boy was much damaged, hence the examination chiefly refers to the former. Czermak, after giving a general description of the condition of the different parts of the bodies, and alluding to the method of embalming and the excellent preservation of the female mummy, which he attributes especially to the natron used in the process, passes to the microscopical details, of which he gives thirteen very carefully drawn figures. On referring to these it will be noticed that Czermak was very fortunate, as he found the striation in one of the voluntary muscles—the sphincter of the eyelid—by making use of turpentine as the examining medium; but this medium failed entirely in my hands, and also upon making a further trial of the same. He does not appear to have obtained the separation into fibrillæ, as his figure is that of a bundle of fibrils. To accomplish this separation it seemed to me to be necessary to swell the tissues very gradually. There is another most interesting point in Czermak's paper, he having been able to recognise the axis cylinder in the fibres composing the median nerve of the arm. It will need no apology to offer a very brief notice of the microscopical details, as his paper may not be of easy access to many of the Fellows.

The following refers to the figures as given in the plate at the end of the paper:—

1. The cells with nuclei of a section of the nail of the ring finger of the female mummy.
2. A longitudinal section near the root of the nail.

* SB. K. Akad. Wiss. (Math.-Naturw. Cl.), ix. (1852).

3. Hair of the head of the female, showing the sheath.
4. A cross section of the hair near the root.
5. The cells of the inner sheath.
6. Henle's and Huxley's layers.
7. A transverse section of the muscle of the thumb, *flexor pollicis longus*, treated with water.
8. The cartilage cells of the ear of the small mummy.
9. Section of the cartilage of the patella, with the cells *in situ*.
10. Cartilage cells from the rib of the female mummy.
11. Nerve-fibres of the median nerve in which besides the nerve-substance the axis-cylinder can be also seen.
12. A few muscular fibres from the sphincter of the eyelid as seen in turpentine, showing the striation and other appearances.
13. A section of the fatty layer in the great toe of the adult mummy, with the fat-cells in position.

Czermak speaks of one of the former Presidents of the Society, Prof. Quekett, having shown him a figure of the hair of a mummy in one of the Nos. of the 'Microscopical Journal.' Unfortunately I am unable to specialise the number.

It will thus be seen that by the aid of the Microscope it has been possible to touch the fringe, and gather up a few threads of "the frayed border of the royal robe" worn long centuries since, but carefully folded up and laid aside as a legacy to the wardrobe of time.