Contributions to the Development of Striped Muscular Fibre.

by

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Through the subject of voluntary or striated muscular fibre has been a much vexed question since almost the infancy of Anatomy, its development has received comparatively little attention till within the last half century. Those observers who have investigated this subject may, we think, be divided into two classes:—those (more especially of the Continental school) who interpret their observations seeming ly biased by a favourite theory; and, those who describe simply what they see, and draw their conclusions from that truthful source alone.

With regard to the

The older views on this subject.

The earliest observations are those of Valentin and Schwann. "Muscular fibre," says Valentin, "arises out of the jelly-like primitive mass in the following manner: Long before separate muscular fibres are perceived, the globules of the primitive mass are seen arranged in longitudinal lines. The globules now appear to approach one another, and in some places entirely... "Valentin's Observations."
in others only on one side—to coalesce and unite into one transparent mass. By this means there arise threads which in many places have a necklace-like appearance; in others are less distinctly notched, and often notched only on one side, the other side being straighter. Subsequently the thread loses every trace of granule or division, and becomes uniformly transparent, defined, and cylindrical. Thus the muscular fibre continues when normal until about the sixth month, except that its substance becomes somewhat more opaque and its cohesion closer. In the sixth month I have recently discerned in these fibres the first traces of transverse striæ. These transverse striæ, however, during the whole foetal life are situated further apart. From the period at which the muscular threads become transparent and uniform, there accumulate between them masses of round or roundish globules, which are somewhat larger than the blood corpuscles. The muscular fibres are formed first and subsequently their filaments.

We have above remarked that from the period at which the muscular fibre becomes uniform and transparent, globules accumulate in large number. Subsequently,
they diminish, and with the jelly-like mass which holds them together - enter into the formation of the mucous tissue. This however unites the fibres.* A few years after publishing these observations just referred to, Balantin wrote another account of his observations, interpreting them according to the cell theory. The conclusions thus arrived at by Balantin and Schwann may be now very briefly noticed.

"In order briefly to recapitulate our researches," says Schwann, "into the generation of muscle, the process may be thus stated. Round cells furnished with a flat nucleus, are first present, the primary cells of muscle. These arrange themselves close together in a linear series; the cells thus arranged in rows coalesce with one another at their points of contact, the septa by which the different cell-cavities are separated then become absorbed, and thus a hollow cylinder, closed at its extremities, the secondary cell of muscle, is formed, within which the nuclei of the original cells, from which the second cell has been formed, are contained, generally lying near together on its wall. This secondary cell, then, passes..."
Microscopical Researches into the Accordance in the Structure and Growth of Animals and Plants; translated from the German of Dr. Schwann. 1847. Page 141.
through all the stages of a simple one. It expands throughout its entire length, whereby the nuclei are further removed from one another, and sometimes even become elongated in the same direction. The deposit of a peculiar substance, the proper muscular substance, takes place at the same time upon the inner surface of the cylinder, by which the cavity is at first narrowed and at length completely filled. The cell-nuclei lie external to this substance, between it and the cell membrane of the secondary cell.

"The transverse strike in the voluntary muscle become more manifest, and the deposited substance is more distinctly seen to be composed of longitudinal fibres, as the protein advances in age. The nuclei are gradually absorbed. The cell-membrane of the secondary muscle-cell remains persistent throughout life, so that each primitive muscular fasciculus is always to be regarded as a cell."

Dr. Martin Bany considers the cells, by the coalescence of which the tubes are at first formed, to be really blood-cells. He says that the blood-corpuscles apply themselves to one another in a linear series; if degrees

the appearance of a cylinder is produced, which becomes more perfect as the partitions between the cells disappear. Therefore, it appears a direct transition of blood dregs into the elementary parts of muscle. The blood-corpuscles, when passing into cells for the formation of muscular fibres, are darker in colour than those destined to form the chorion. There seems to occur in them an increase of the red colouring matter.

M. Seibert thus describes the development of striated muscular fibres in the heart of the chick: "The rhythmic contractions of this organ become very manifest and regular towards the 35th hour of incubation; nevertheless, it is at this time composed of nothing else than organo-plastic globules or elementary cells embedded in a granular blastema. Between the fourth and fifth days of incubation, in the midst of the mass of globular particles certain elongated subcylindrical bodies, sometimes grouped together in a reticular manner, these bodies being the first rudiments of the muscular fibres not merely in the heart but also in the other striated muscles, he designates "myo-
genic cells." Between the 7th and 8th days, the organo-plastic globules undergo a considerable diminution, and the muscular substance presents a more complete development. A longitudinal striation shows itself in the contents of the cylinders, which seems partly due to the grouping of the granular particles of which these contents consist; the transverse striations do not show themselves till some time afterwards. The organo-plastic globules which at first separated the primitive cylinders gradually disappear; the cylinders approach one another, and before the end of embryonic life they are found to be grouped into fasciculi.*

Now briefly to notice Professor Remak's observations on the development of muscle in the Tadpole. Examining, he says, a portion of muscle from the centre of the back of a Tadpole, there are seen globules (Bottargelina) arranged longitudinally in the axis of the body. Also large, simple, round, nucleolated nuclei lying almost in the middle between the two ends of the cylindrical cell, so that, reaching to the side of the cell, they occupy only half the breadth of the cylinder, while the other half as well as the remaining space in the cell is filled up by the yolk.
granules (Dotterkörnchen), some of which are square-shaped, which are held together by the tough blastema. At an early stage of development each cylindrical yolk-cell has four round nuclei, of which two lying opposite each other are found in the centre of each cylinder: this arrangement is said to be of great regularity and symmetry. Later in development the nuclei increase to 3, 4, or even 5 in number, arranged behind each other in the longitudinal direction of the cylinder. The yolk-cells Remak considers to be formed by the lengthening of previously existing highly nucleated cells and by the multiplication of nuclei. At this stage the primitive muscle has a distinct, fibrous longitudinal construction and a delicate transverse striaion of the homogeneous blastema.

The conclusions Professor Remak arrives at from his investigations are stated as follows:

1. The Primitive Muscle bundles arise not from a melting together, but from a prolongation of the yolk-cells in which the number of the nuclei is increased. This statement holds good undoubtedly in the case of those cylindrical muscle-cells in which the formation of trans-
verse markings has already begun, and is very probably the case in the earlier stages.

2. Before the appearance of the transverse strife, the cylindrical muscle cells may fall to pieces in their longitudinal direction.

3. As soon as the cylindrical muscle cells show signs of contractility, so soon also is an indication of transverse markings observable.

4. While the nuclei and the yolk-granules occupy one side of the cylinder, the transverse strife show themselves (as foldings of the homogeneous blastema) on the other side, and develop themselves in the same proportion in the first half as the yolk-granules disappear in it.

5. The nuclei of developed Primitive muscle-bundles belong originally not to separate cells, but increase independently, and at first with a certain symmetry and regularity within the elongating muscle cells.

6. Till the disappearance of the yolk-granules takes place, no sheath is observed on the muscle cylinders. In the latter
*Ibid. Page 308.*
at no time is a cavity to be observed. *

The last Researches to be shortly referred to in this section are those of Professor Kolliker. He considers the sarcoplasm of a muscular fasciculus to represent the "sum of the membranes of the coalesced cells"; the muscular fibrillae to be the altered contents of these cells become solid; and the nuclei of the youngest fasciculi to be the original cell nuclei, whose descendants are represented in the nuclei of the older fibres, which have multiplied by an endogenous process." Professor Kolliker thus describes the process of development in the muscle of the human embryo:

"The primitive fasciculi, in the human embryo, at the end of the 2nd month, present the aspect of elongated bands, 0.001" to 0.002" broad, with nodular enlargements at different points, at which places are situated elongated nuclei; the bands exhibit either a homogeneous or a finely granular aspect, and but rarely a faint indication of striation. In their further development these primitive muscular fasciculi continue to increase in breadth and length, and their cell cavities are developed into the muscular fibrils. The tubes, moreover, as at first, present nuclei lying close
upon the sarcolema, which frequently cause rounded elevations on the surface of the tube, and may be observed actively engaged in the process of multiplication; they are much more numerous than previously, and most frequently disposed in pairs closely approximated, but often also in groups of 3, 4, or even 6, either contiguous or arranged serially.”

The more recent views on this subject.

From the sequel it will be observed that the researches we have above quoted were correct to a certain extent, as is proved by the observations about to be described, and those investigations would be of still greater value had their interpretations not been tainted by theories.

According to the recent researches of Messrs. Savory and Lockhart Clarke, which I have for the most part confirmed in my investigations, the development of muscle may be thus described. There is present at first a clear, granular blastema from which certain round and oval bodies, of a globular form and granular aspect with distinct nuclei, are formed. [Plate I. fig. 2, and Plate II. fig. 7]. These cytoplasmic nuclei,
according to the focus by which they are seen, appear either characters of
like fat globules, – as transparent bodies with a distinct the cytoplasm.
Dark, smooth border, – or have a granular aspect generally with a distinct nucleolus, granular contents, and showing a clear space immediately within the delicate border
which limits them and between it is the granular contents.

[Plate X. fig. 1 and Plate II. fig. 2]. These cytoplasm is
round or oval in shape, and vary very little in size
in different animals, but are met with of different
sizes in the same animal; in the Frog, Tadpole, Fetal
calf, and chick, I have found them to measure on
an average from $\frac{4}{1000}$ th. to the $\frac{1}{2050}$ th. of an inch in
length, and from the $\frac{4}{1000}$ th to $\frac{1}{2730}$ th of an inch in breadth.
The oval and round cytoplasm are also present in the
early forms of contractile substance which exist among
the lowest groups of the animal kingdom, viz. the
Protozoa and Radiata, e.g. in Sponges and Polyps.

[Plate IV. figs. 183]. In all these characters they are
similar to the cytoplasm in the primitive muscle of the
Vertebrata, except that they are for the most part,
somewhat larger. The nucleoli of the cytoplasm are
characters of the
they can be distinguished as such, are bright particles
defined
of a round form, colourless, with a smooth,
outline, and refract light strongly like oil globules; they vary in size and measure on an average 12,000 th of an inch in diameter. Besides these structures there are seen, at this stage, in the blastema, numerous round, transparent, highly refracting particles possessing the same characters as the nucleoli of the cytoblasts, measuring from 1200 th of an inch in diameter to a size much smaller. The nucleoli are most commonly one or two in number in a cytoblast; occasionally a cytoblast possesses three nucleoli; and very rarely are four present in the same cytoblast. The bodies which are present in the blastema and which resemble the nucleoli of the cytoblasts are probably partly the nucleoli of cytoblasts yet the formed partly those of disintegrated cytoblasts.

With regard to the effects of reagents on these structures, my observations are made on the molecular blastema, cytoblasts of the muscles of the thigh blastema of a chick on the 9th day of incubation. Acetic acid renders the walls of the cytoblasts much more delicate and transparent, almost as if they were dissolved; and thus the contents become more distinct. [Plate IV. fig. 2 b]. This effect is similar to that produced on pus cells by the same
reagent. Acetic Acid renders the blastema more transparent. Simple sugar causes the cytoplasm to be contracted by ice water, and to present somewhat irregular forms. On the use of a saline solution the cytoplasm shrunk up, and were evidently chemically affected. Water scarcely at all affects them; it only renders them very slightly more transparent by endosmosis. It renders the blastema slightly more transparent. On the addition of sulphuric ether the nucleolus & contents become perfectly distinct, and refract light strongly. This effect was not so strongly marked in the case of the free floating cytoplasmic as in that of those embedded in the blastema. [Plate II, fig. 3.6.] The contents in some cases appear as the remains of the cytoplasm; in others as if escaping from the cytoplasmic. [Plate II, fig. 3.7.] Liquor Potassae causes the contents of the cytoplasm to appear very clear, as if dissolved; and the cytoplasm itself, refract light more strongly on changing the focus. They, moreover, are diminished in size, and present irregular forms seemingly from the collapsing of their walls after their contents are dissolved. Their chemical nature then, as inferred from the above actions of reagents on both the cytoplasm & blastema, may, I think,
be stated to be deamininous. The effects of these reagents on the cytoblasts prove also, that they are surrounded by a very delicate transparent membrane. Their globularity is shown by the effect of changing the focus which I have alone described. Lastly, the fact that the cytoblasts do not change their form while the blood corpuscles alter their shape on passing through a narrow channel, proves that the walls of the former are not so elastic and their contents less compressible (i.e. less fluid) than those of the latter.

The next stage in the process of development of striated muscular fibre, consists in the fibrillation of the blastema along the sides of the nuclei, to which latter the fibrillae so formed become adherent. [Plate II. fig. 16]

Sometimes these lateral bands or fibrillae enclose a single nucleus with conical processes of blastema, so that the object occasionally presents some resemblance to a flat form nucleated cell. More frequently, however, they enclose a linear series of nuclei or cytoblasts at variable distances from each other, but cemented together by blastema, which sometimes forms round each a more or less definite shape. Sometimes a series of the cytoblasts overlaps each other in an imbricate form, and are cemented together by a common layer of blastema. Acetic Acid. The effect of
added to these early forms of muscular fibres renders them more transparent, and the cytoplasm more distinctly visible in their axes. As will be seen in my drawing already referred to, as also in [Plate II. fig. 4.a], the cytoplasm lies with their long axes in the direction of the fibre, in which point I differ from Mr. Savory. Mr. Savory says that "the nuclei or cytoplasm are not at first generally arranged in a single series; but two, three, or even more occasionally lie side by side in apparent disorder." [Plate I. fig. 3]. Almost, if not quite, as soon as these cytoplasm are thus aggregated into these long masses, they become invested by blastema, and this substance at the same time appears to be considerably condensed, so that the outlines of the nuclei become almost or completely obscured. The fibre thus appears to be irregularly cylindrical, or somewhat flattened. It is so opaque that its interior is no longer to be plainly discerned, and its surface is rough and uneven. These nuclei, thus aggregated and invested, next assume a much more regular position. They fall into a single row (with remarkable regularity) and the surrounding substance at the same time grows clear, more transparent, and is arranged in the form of two bands bordering the fibre, and bounding the extremities of the nuclei so that they become distinctly visible. [Plate I. fig. 4]. The nuclei
have now become decidedly oval and closely packed together side by side, so closely indeed that they appear as if compressed. Thus they form a single row in the centre of the fibre with their long axes lying transversely, and their extremities bounded on either side by a thin, clear, pellucid border of apparently homogeneous substance. No structure can be discerned between the nuclei; they lie in close contact, except towards their extremities, and even appear as if pressed together. This regular arrangement of the nuclei does not always take place uniformly throughout the length of the fibre, but it sometimes is bulged out at the one end by an aggregation of the nuclei. Sometimes, also, along the fibre an occasional nucleus lies obliquely instead of transversely." *

This jibilation of the blastema presents an appearance closely resembling that of the contractile substance of the Radiata. Compare Plate IV, fig. 2, with Plate II, fig. 16.

The next stage in the process of development is the increase in breadth of the fibres by the formation of lateral bands along the margins of each. My observations confirm those of Mr. Savory, who says: "The bands of tissue forming the borders of the fibre, and bounding the extremities of the nuclei, at first thin and pellucid, soon
increase in thickness by the addition of the surrounding blastoma to their outer surface... They increase in breadth, & this increase is due to the addition of fresh material upon their exterior, and not to a deposit on their inner surface; for the extremities of the nuclei are not encroached upon, and the outline of the fibre, which is at first even and well defined soon becomes rough & irregular, obviously from the addition of fresh material. The fibres next increase in length and the nuclei separate; the nuclei remain no longer in close contact, small intervals appear between them, and as they have more space they increase in width & become more nearly circular. The spaces between the nuclei rapidly widen until at last they lie at a very considerable distance apart. [Plate I. fig. 4. and Plate II. fig. 4. a.]. At the same time the fibre decreases very considerably in diameter: for as the nuclei part from each other & as the spaces between them increase, the bands which they separated fall in, -- approach each other and ultimately coalesce. [Plate I. fig. 5. a. and Plate II. fig. 4. b.]. This falling in of the lateral bands, as the nuclei separate and their
ultimate coalescence, afford evidence for believing, that when they were separated, there could have existed but very little intermediary substance between them among the nuclei.” Acetic Acid added to muscular. Effect of Acetic fibres at this stage renders them more transparent and Acid in the fibres. the cytotoblasts in their axes more evident.

During the next stage of the process, some the stage in which of the nuclei or cytotoblasts of the fibres at intervals decay, the nuclei are that is, become broken up into clusters of granules; and, the lateral bands cannot be distinguished as such having coalesced with the substance between the nuclei to form a cylindrical fibre. [Plate I. fig. 5. a. e. and d; and Plate II. figs. 45, 13, and 14]. Before they thus break up, the nuclei or cytotoblasts generally increase in size and become more round in form; their granular contents are multiplied, and the white border, formerly observed just within their wall, disappears and is replaced by granules; moreover the granules nearest the nucleole become larger. [Plate II. fig. 3 a.] Soon the place of the cytotoblasts are successively occupied by clusters of
Y Savoy: Pages 246 to 248.
granules, [Plate I. figs. 3, a, b, c, d, e; and Plate II. fig. 42, and figs. 13 & 14] which in their turn become obscure, and are ultimately lost sight of, on account of the increase of the sarcous element. Before they are lost sight of the granules are observed to separate from each other along the length of the fibre and to become more scattered. [Plate I. fig. 5. d. and e.] The lateral bands by this time have coalesced and become one with the fibre, and the cytoplasm or nuclei occupy the centre of the fibre being bordered by the lateral bands. According to Mr. Savory the nuclei may dissolve either while they are lying with their long axes across the fibre, or they have changed their position before they are broken up into clusters of granules.

In the earliest fibres these changes proceed more rapidly in the later fibres than in those of later development. "In some of the this stage is retarded, later fibres," says Mr. Savory, "this separation of the majority of the nuclei, seems scarcely to occur at all; while but a small interval exists between them, and while their oval form is still preserved, most of them perish in their places, with their axes still lying transversely; and the positions marked for a time by clusters of granules extended transversely at frequent intervals along the course of the fibre." [Plate I. fig. 5. e.]
The appearances, which distinguish the next stage in the process of development of muscular fibre, are those of a delicate but distinct longitudinal striation, succeeded soon by faint transverse markings at intervals along the margins of the fibres. The longitudinal striation gives the fibres an appearance very like that of the contractile fibres met with among the Mollusca and some of the Annelida. Resemblance of lora [Plate IV. figs. 5, 6, and 7]. Only in these lower classes fibres at this stage of the Animal Kingdom, the ootoblasts are absent, and to those of the und the fibres have the striking glinting aspect of ligamentous lora or annu. tissue. "A faint indication of the appearance of the trans lora. verse striæ", says Savory, "may sometimes be observed in the lateral bands, almost as soon as these are fully formed; [Plate I. fig. 5 f.] and as these bands approximate, the striæ become more plainly marked and often contrast strongly with the intermediate and apparently homogeneous central portion of the fibre." The striæ are first discerned at the margins of fibre and gradually pass towards the centre. [Plate I. fig. 10 and Plate II. fig. 10.] Before the transverse striæ appear, according to my own observations,
the longitudinal striation is perfected; but sometimes
the transverse strie are not plainly marked, because
of the greater amount of the superposed blastema on
the centre of the fibre. On the first appearance of the
transverse striation a few streaks are seen here
and there along different portions of the margins
of the fibre, and these gradually extend and meet
in the centre of the fibre, giving to the fibre a true
an irregularly streaked appearance, until at length
they are seen throughout its entire substance, but
for a long time they are most prominently marked
towards the margins. The strie are smaller and more
close together in the fibre than when it is fully grown.
It is not to be understood from the above description that
the transverse strie are actually bars of blastema com-
mencing at the margins and uniting in the centre of
the fibre, but such is the appearance that the transverse
strie present in the earlier forms of muscle. The
actual mode of development of the transverse strie
will be treated of in a separate section. Acidic Acid
causes the sarcolumma of fibres at this stage to become
acid in the fibres. Action of Acid
This last may be considered to be the final stage in the development of the Primitive Muscle Fibre or Elementary Fasciculus, what follows being the increase in breadth of the Fasciculus by the additional later formation of lateral bands, under the agency of cytoblasts, which ultimately coalesce with the fibre, the splitting up of the Fasciculus longitudinally into fibres, which I consider to have begun before the appearance of the transverse striae and which is indicated by the delicate longitudinal streaking of the fibre stated as observable at that period; the formation of the Sarcolemma or sheath of the Fasciculus, and the complete development of the transverse striae. But before proceeding further we may take a view of a Primitive Muscle Fibre as it now presents itself, undergoing the later stages of its development at different rates along its length. The Primitive Muscle Fibre or Elementary Fasciculus possesses a very uniform appearance throughout its entire length. It appears as a narrow, cylindrical band, with more or less smooth margins. The nuclei or cytoblasts that remain are seen at tolerably regular intervals in its substance, generally at an equal distance from either margin of the fibre. They are large, round, or somewhat oval in form, with their long axes in the direction of the fibre.
Between them, widely scattered clusters of granules are seen—
the remains of those which have perished, and which
soon become obscured through the formation of the sarco-
lemma. Passing towards the opposite end of the fibre,
we see the longitudinal striation of the fibre distinctly,
and the transverse striæ are evident, especially along
its margins, as also granules in clusters or isolated.

The study of the Comparative Anatomy of Muscle furnish-
us with no marked analogy among the lower animals to the
stage in the development of the striated Muscle of the An-
telopoda characterised by the first appearance of the transverse
striæ. The lowest type of animals in which I have met
with an indication of transverse striation is among the
Amphipoda; but in the muscle of these animals it seems to
be only superficial, connected with the sarcolemma and
not with the ultimate structure of the muscular fibres.

Examining the fasciculi they present the appearances of a
delicate but distinct striation [Plate IV fig. 8 and 9.];
on dissecting, however, these fasciculi into fibrils, they show
no indications of transverse striæ [Plate IV fig. 9 a d and e].

With regard now, to the increase in
breadth of the fully formed Primitive muscular fasci-
culus, this is carried on by means of the surrounding

On the growth in
cytoblasts, which are very numerously scattered amongst the fibres. They may be seen to arrange themselves in a linear series along the margins of the Primitive Muscle-fibre, just as those of the preceding lateral bands had done, with their long axes in the longitudinal direction of the fibre; they become attached to either margin of the fibre, and invested by a layer of surrounding blastema which passes from one cytoblast to another. Thus a continuous band of fresh material of greater or less extent is added to one or both borders of the fibre. [Plate I, figs. 9, 10, and 11]. These layers or bands of fresh material are at first clear and pellucid, like the original border of the fibre when first formed, and present a striking contrast to the present appearance of the substance of the fibre. These bands are at first readily detached from the fibre, [Plate II fig. 12] but they soon become intimately connected and inseparably blended with it. The striæ and other characters of the adjacent portion of the fibre are soon acquired, and by degrees the cytoblasts disappear.

"Fetal fibres rarely possess the same diameter throughout their entire length, owing to the fresh material which has been recently added causing bulgings and tiny fasciculi by the addition to their exterior of bands of sarcoœ material formed from the blastema by the agency of cytoblasts."
at intervals; but each inequality gradually disappears. As the fibre acquires its more perfect characters, so its substance becomes condensed; it diminishes in size, but this decrease in breadth is not accompanied by a corresponding separation of the nuclei, and the fibre becomes less transparent. The nuclei in its interior grow much more obscure, and they are at length concealed by the increasing density of the muscular substance.*

This obscurity of the cytoplasm is owing, I think, not so much to changes taking place in the fibre itself, that is to say by the consolidation of its substance, as to the formation and increasing thickening of the sarcolemma. “As a general rule, all fresh material which is added to the fibre before the original nuclei separate, is attracted independently of fresh nuclei; but that which is added after the original nuclei have separated or become disintegrated, is by means of the additional nuclei which are attracted to the exterior of the fibre.”* As growth advances the substance of the fibres gradually increases in denseness and firmness.

In order to render more complete my account of the Development of Striped Muscular Fibre, I
* Savory: pages 250 and 251.

will here briefly refer to the views held with regard to
the growth of a muscle considered as an individual organ.

German anatomists have devoted more attention to the
solving of the question, as to whether a muscle increases
in size by the formation of new fasciculi during infant
life, or by an increase in length and breadth of its com-
ponent primitive fasciculi. "The growth of the entire
muscle," says Helhiker, "is chiefly to be referred to the in-
crease, both longitudinal and in thickness, of the pri-
mitive fasciculi, and the rudiments of all the future
primitive fasciculi appear to be formed, probably even
as early as the original rudiments of the muscle itself-
in every case at the middle period of fetal life." In the
human embryo "at the 4th or 5th month, they are per-
haps five times as thick as in one at 2 months; in the
new-born infant they measure for the most part twice,
occasionally even three or four times as much as in the 4th
and 5th month; and in the adult their size is perhaps
five times greater than in the new-born child." *

Budge thought to decide this point by
counting the number of the fasciculi present in the
transverse section of a given muscle in a young animal.


and then comparing it with that in the same muscle Budge considered of a full grown animal; and he found in the latter case new muscular fibres a larger number present than in the former, so he concluded "that during growth new muscular fibres are formed." *

Margo in his researches holds that the growth of muscle is caused by fusiform cells developed from the sarcoplast, which lie in rows with their ends overlapping each other; then the partitions between them dissolve, and the fibres thus formed acquire all the characters of striated muscular fibres; the whole of this process taking place within the sarcolemma. * Weismann, on the other hand, considers that the sarcolemma is divided as well as the sarcous substance of the fibre in the process of splitting, the increase in size just as the cell membrane is in the case of cell division, box of the fasciculi. Weismann, when writing on this subject of adult muscle to test the growth of an entire muscle, and in discussing arise by a process of Budge's and Margo's views, states that "no doubt there splitting of the fibres is an increase in the number of the fasciculi composing and thus sarcolemma an adult muscle, as compared with it in the fetal state; but says, at the same time it is to be noticed that such muscles possess a great many fasciculi which are narrower and finer than the majority of the
Ibid: S. 269.
fasciculi. These he considers to be newly developed fasciculi, that is to say fasciculi which did not exist in the embryo state of muscle, but are in truth subdivisions of the older fibres, as he speaks of them, as daughter fibres arising from a splitting up of the mother fibres.

The conclusions which he has arrived at from his observations are as follows:—That the growth of muscles takes place in the frog partly through increase both in length and breadth of the embryonic fibres, and also by a multiplication of these fibres. The latter process takes place thus: first the nuclei increase in number by division and are arranged in thickly crowded rows. These rows lengthen themselves towards both ends of the fibres. Next the fibres become lengthened, narrowed, and flattened, and are split longitudinally between the rows of nuclei, so that in each division of the fibre there lies a row of nuclei. Each one of the thus newly formed fibres continues the process of division still further as before, splitting into many neighbouring fibres of different breadths and containing each a row of nuclei of greater or less size. And, lastly, transverse striation takes place in the fibres. It seems to me not improbable, he continues, that thus by degrees an entire

Weismann's account of the mode of growth of muscles.
*Ibid. S. 280 und 281."
renewal of the whole fibres of a muscle takes place.*

Not having specially investigated this point, but having already shown that the growth of the individual fascicule of fetal muscle takes place by means of lateral bands formed under the agency of cytotblasts and becoming one with the fibre, this conclusion appears to me highly probable; namely, that in the aftergrowth of the entire muscle in the adult animal, there is no new formation of fasciculi after their cytotblasts have disappeared. In the human foetus about the middle period of fetal life, and in the lower vertebrates at a corresponding period, I have observed the muscles to be surrounded by separate sheaths or fasciae, and their tendons to be perfectly developed so that their form and attachments are probably fully acquired between this period and the end of fetal life. Their after-increase in bulk is produced by an increase in the length and thickness of the original fascicule, and perhaps also by a multiplication of the same through division, not, however, as the tawn them, or perhaps German anatomists suppose, by means of rows of nuclei by multiplication. I doubt the greater amount of connective tissue being due to division.
*Lockhart Clarke: Transactions of Philosophical Society.
fat present in adult muscles between the fasciculi adds materially to the increased size of such muscles.

Here it is appropriate to refer briefly to the development of striped muscular fibre in the human foetus. The process takes place according to the same general plan in the human embryo as it does in the chick and other vertebrates. "In the human foetus," says Lockhart Clarke, "from about ⅓ to ⅔ of an inch in length, the first stage of development may be seen to commence by the formation of fine lateral bands or fibrillae along one or both sides of one nucleus or more," [Plate III.B. fig.1]. "When, however, there are more nuclei than one enclosed by the same lateral bands, they are always disposed in linear succession with their longer axes in the direction of the fibre," [Plate III.B. figs.3 and 6]. "Thus formed, they lie side by side in bundles of different sizes, to which new fibres or new fibrillae are being continually added by a renewed process of development." * At first these lateral bands or fibrillae can be easily detached from the fibre, [Plate III.B. fig.2], but afterwards they become inseparably blended with it. The cytoplasm next breaks up into clusters of granules, [Plate III.B. fig.3]; then the longitudinal
striation shows itself in the fibre [Plate III. B. fig. 4]; next the transverse striae make their first appearance along the margins of the fibre [Plate III. B. fig. 5]; and at last the process is completed by the perfect development of the transverse striae [Plate III. B. figs. 9, and 10]. The growth of the elementary fasciculi takes place as in the Vertebrata generally by means of lateral bands formed under the agency of cytotblasts being added to the margins of the fibre and becoming one with it, as has been already described, [Plate III. B. fig. 7]. The original formation of the transverse striae and sarcotunica, as it will be described in the next section of this paper, takes place after the same manner in the human embryo as in the Vertebrata generally. [Plate III. B. figs. 11 and 12.]

In the Development, then, of Stripped Muscular Fibre among the Vertebrata including man, the following steps may be traced. From a molecular blastema, oval or round bodies, termed cytotblasts or nuclei, are first formed; next follows the aggregation of these cytotblasts and their investment by the surrounding...
blastoma; their regular arrangement into linear series along the thus formed fibres; the formation of lateral bands; the lengthening of the fibre and separation of the nuclei; the blending of the lateral bands with the fibre; the breaking up of the cytoplasm into clusters of granules in the axes of the fibres; the longitudinal striation of the fibres; and, lastly, the appearance of transverse strie first along the margins of the fibres passing gradually towards their centre. These several steps or stages of development are not observed to occur in the fibres in invariably consecutive series, but often two or more are seen to take place at the same time in the length of a fibre. Moreover the rate of development varies in various muscles as well as in the various fibres of the same muscle.

On the origin of the Transverse Striae, and of the Sarcolemmata.

With regard to the formation of transverse strie in the Primitive Muscular Fibre or Elementary Fascicula, it is to be noticed that none of the above observations have attempted to account for them otherwise than by
considering them to be foldings of the blastema. This is perhaps owing to former observers having examined the developing striped muscular fibre of the vertebrate only in the fresh state without having noticed the effects of various reagents on it. Nor, on soaking muscle during various lengths of time in Chronic Acid, can more easily the transverse striations be rendered more evident and can be traced even in the fibres of the fasciculi; owing, doubtless, to that Acid coagulating the albumen of the fibre, thus rendering it more easily dissected into fibres. This effect of Chronic Acid was so striking that it led me to repeat the experiment several times and in various ways. The results thus arrived at will form the substance of most of this present section.

On soaking a portion of muscle from the back of a Frog Tadpole about 1 1/2 inches long, for 4 or 5 days in a weak solution of Chronic Acid, the muscle is harden ed and its Fasciculi can be easily dissected into Fasciculi. Examining how an Elementary Fasciculus thus dissected into fibres, [Plate II. figs. 8 and 15; and Plate III. A. fig. 14 showing the same tinged by carmine], it
will be distinctly observed, I think, that a fibroblast, which is on an average the 1/500th of an inch in diameter, presents the appearance of two very narrow clear lines enclosing between them a linear series of globular spherical particles connected together by intermediate lacunar substance, having thus the appearance of a row of beads. [Plate II. fig. 5 B.; Plate III. A. fig. 5, the same tinged with carmine; and Plate III. B. fig. 11, showing fibroblasts from human umbilical cord].

Each fibroblast is, however, in truth more or less of cylindrical form as the fascicles are. On altering the focus, the portions of the fibroblasts which were light before appear darker than the intermediate spaces which before appeared dark. which is described by Dr. Dobie as occurring also in the striated muscular fibroblasts of adult animals, and which is represented in Plate II. fig. 5 A.; and Plate III. A. fig. 6, tinged by carmine, and in Plate II. B. fig. 11. Dr. Dobie states moreover, that in the muscular fibroblasts of various animals "the clear space can be distinctly seen to have a dark line crossing it transversely and dividing it into two equal parts, and that the dark space also presents a similar division caused by a line which is..."
Ibid. Page 115.
generally seen of a lighter shade than the other parts of the "space". That these spherical light particles are globular, seems to me, to be proved by the changes produced on altering the focus: for with a distant focus they appear as clear particles, and, by gradually altering the focus, various portions of each of them are seen, till with the nearest possible focus they appear quite dark. [Plate II. fig. 5 b.c.a.] By degrees as growth proceeds and the intermediate sarco-lemmal substance becomes condensed, these globular light particles lose their sphericity though not their globularity, until in the fibres of fully grown muscular fibre they present a quadrilateral form. This explains also, I think, the appearances described by Dr. Döble as occurring in the striped muscular fibre of certain animals, thus: the dark line sometimes seen crossing a clear space is the remains of a dark space which was once of the same size as the others, and which separated two adjacent clear spaces. Likewise, the somewhat light division present in certain dark spaces is probably the remains of a light space which existed between two neighbouring dark spaces. These
Spherical light particles seem to be derived partly from among the larger molecules of the blastema, and partly by an increase in size of the granular contents of the cytoplasts after they are dissolved. Such molecules increase in size both by their inherent power of growth, and by the coalescence of two or more smaller ones to form a large one, just as in the case of oil globules. On changing the focus these molecules present the characters of the clear spaces of the fibrii, which have been above mentioned. The light particles of the original fibrii are globularly spherical in form, colourless, with a smooth, well-defined, dark edge, transparent, possessing a delicate wall enclosing probably semi-fluid contents which cannot however be distinguished as such under the microscope, and they refract light strongly like minute oil globules. In size they measure on an average the breadth of an inch in diameter. The dark, intermediate portions of the fibrii, on the other hand, seem also to be surrounded by a delicate wall, but they have a different molecular character from those of the light particles. Their becoming gradually less dark as the focus approaches nearer than is going, I think, to more...
light passing thru through their contents than when the
focus was more distant. That the clear particles, on the
other hand, should appear darker with a near focus
requires, I think, the supposition that they possess semi-
fluid contents which are thus only brought into view
by a near focus. That these particles have each a
very delicate enveloping membrane is very difficult
to be demonstrated. But it may be reasonably sup-
posed to exist from the following considerations. The
fibrillee possess a well defined contour indicated by
two parallel lines. Again, in preparations of fibrillee
put up in alcohol when the latter had evaporated,
the fibrillee are narrowed and the clear particles more
especially appear thinner as if from the collapsing of
their walls. This may be more or less remedied (ac-
cording to the age of the preparation) by adding alcohol
and then the clear particles are observed to swell up.
Lastly, in the contracted state of the muscular fibril-
lee the dark spaces are observed to have approached
each other, which could occur only from their being
connected to each other by some delicate membrane,
for if there were nothing holding them together, it is to
be expected that during the changes they constantly undergo in contraction and relaxation the dark particles would be very liable to displacements, which however never do take place. Thus a fibrilla may be described as a more or less flattened cylinder subdivided into particles varying from each other in the molecular character of their contents.

That the transverse striæ should be evident sooner in the lateral bands than in the fibre itself may, I think, be accounted for by two reasons: 1st, Because the lateral bands are not so dense, and therefore more transparent than the fibre itself. And 2nd, because the light acts more strongly on the margins of the cylinder than on its centre. In some cases perhaps also, because the cyto blasts of the lateral bands are broken up sooner into clusters of granules than those of the fibre itself.

Seeing then, as I think ought to be more evident, that what are commonly termed the "clear spaces" of the fibrillæ are in truth not spaces but particles possessing delicate transparent walls and probably containing fluid contents; the next question that occurs is, does this observer—
tion throw any light upon the probable Physiological Function of these so called "clear spaces"? I consider these globular clear particles to be "spaces" is, I think, opposed by the striking change produced on them by altering the focus gently, as I have above described it and endeavoured to represent it in my Plates; for if they were spaces they ought to exhibit the characters of flat bodies and remain unaffected by change of the focus, which they do not. This view seems to me to be strengthened by the very striking resemblance they bear to oil globules. The generally recognised definition of them as "clear spaces" does not permit of any function or use being ascribed to them. After the above minute description of them, in my estimation, there is nothing inappropriate in considering the light particles of the fibrillae of striated muscular fibre to be reservoirs of pabulum or stores of nutritious material derived originally from the capillaries, and brought thus into more immediate connection with the proper sarcolemna substance. Professor Helz has lately described a considerable number of nuclei to be present in every nerve, which are held to perform the same function in that tissue. The constant time and more to which
Muscular fibre is subjected on account of its physiological function, as also the fact, which seems the true though it has not been absolutely demonstrated to be the case, that the bulk of muscle is for a certain time added to as growth advances and is then arrested, renders it not unlikely that the vital property of contractility is supported by the existence in the fibres of stones of pabulum, which the clear spaces may be considered to contain.

And, lastly, no vessels have as yet been found to enter through the sarcoleumina into the substance of the fasciculi, which leads to the supposition that the muscular fasciculi must have some inherent source of nutrition.

The last point which requires to be noticed with regard to the development of the Primitive Muscle fibre or Elementary Fasciculus, is the formation of its sarcoleumina. The sheath of a Muscular Fasciculus is of such extreme delicacy even in the adult muscle that one cannot easily perceive or recognize it when it makes its appearance.

Hence arises the difference of previous observers and the hesitating terms in which they have reached their views as to this structure. Of all these observers, Remak speaks most decidedly about it, and his surmise, I think, is actually
the way in which the sarcollemma is formed under the agency of cytotubules. My attention was directed to this point by carefully looking at some of my preparations, the fibres at the margins of which were injured by becoming slightly tubed by the surrounding asphalt. Were it not for this circumstance this point would have remained unnoticed by me; but I hope my drawings and specimens together will tend to establish my view. The appearances which lead me to think that the sarcollemma of the Elementary Muscular Fasciculus is formed by a delicate layer of various elements raised above the surface of the fibre by the agency of certain cytotubules are as follows:—At the fibre advances in development from its earliest form, and as the fibre or fasciculus lateral bunches become by degrees one with it, some of the cytotubules are observed to rise to the surface. This has been observed also by Lockhart Clarke. This appearance was confirmed to me by the specimen already alluded to in which the cytotubules alone are affected by the asphalt. Some of the cytotubules are distinctly seen to be nearer the surface than the cytotubules of the fibre which are being dissolved. [Plate II. figs. 6, 7 and 9]. The cytotubules of the sarcollemma may be also rendered more distinct by the
[Plate III, B, fig. 12.]

use of carmine. 2ndly, that the cytoblasts carry with them a delicate layer of sarcous substance connecting them to each other, is very difficult to be actually demonstrated. But it is rendered very probable, seeing that, as has already been mentioned, the longitudinal striae of the fibre and the clusters of granules in its axis into which the cytoblasts have broken up, become more obscure as development advances.

Conclusions.

As to the conclusions then, that may be drawn from the preceding account of the Development of Striped Muscular Fibre in the Vertebrata, including man.

1st. Muscle is originally developed from a molecular blastema of an oello-albuminous character, in which uninucleated nuclei or cytoblasts with granular contents are first formed.

2nd. The blastema undergoes a process of fibrillation, the cytoblasts being linearly arranged with their longer axes in a line with longitudinal direction of the fibres, being connected together by blastema, and bounded by two parallel fibrillae or bands.
3rd. With regard to the progress undergone by the cytoplasm. They become more granular, larger, and more round, and at last are broken up into clusters of granules.

4th. With regard to the development of the muscle fibre. It becomes more condensed by the constant addition of portions of the surrounding blastema; lateral bands are formed on its margins, which ultimately coalesce with the fibre; longitudinal striation shows itself in the fibre; and, somewhat later, transverse striae are observed at different points along the margins of the fibre. In the fresh state of the fibre this striation becomes by degrees more and more obscure from the increase of blastema on its surface.

5th. Increase in the breadth of the elementary muscular fasciculus is accomplished by means of lateral bands possessing cytoplasm becoming formed on each margin of the fibre and ultimately coalescing with it, as also by the gradual addition of portions of blastema without the agency of cytoplasm. Increase in the bulk of adult muscle is due to the lengthening and thickening of the original embryonic fibres, perhaps to a multiplication by division of the same, and by a greater amount of
connective tissue and fat being formed between the fascicles:

6. The longitudinal striction observed in the fibre indicates the splitting up of the elementary fasciculus into fibrillae; and it cannot be seen at a later stage because of the accumulation of the blastema on the surface.

7. The light particles in the fibrillae are originally formed of spherical globules in linear series along a fibrilla with intermediate sarcolemma substance connecting them together. At a later date these spherical globules become quadrilateral from the pressure caused by the condensation of the intermediate substance.

8. These light particles in the fibrillae are probably reservoirs of nutritional or nutritive material, and serve to distribute the nutrient derived from the capillaries on the surface of the sarcolemma among the nuclear substance of the fibrillae.

9. The sarcolemma of the muscular fasciculus seems to be formed originally as a thin layer of sarcolemma substance on the surface of the elementary fasciculi, which is raised above the fibre by means of cytotheca: and these cytotheca probably remain permanently as the nuclei of the sarcolemma of adult fasciculi.
A certain analogy exists between the appearances presented by the development of striped muscular fibre in the vertebrata including man, and those which contractile substance presents in the various classes of the animal kingdom.
Explanation of Plates.

Plate I.

Fig. 1. Cytoplasm from the tissue of the dorsal region of a postnatal pig, one inch in length.

Fig. II. Section of muscular fibres from a postnatal pig, between one and two inches in length. The first stage in the formation of muscular fibres.

Fig. III. Muscular fibre from a postnatal pig, between 2.5 and 3 inches long, showing the linear arrangement of the nuclei and the narrow bands.

Fig. IV. Fibre from a postnatal pig, 3 inches long, showing separation of the nuclei.

Fig. V. a. Fibre from a postnatal pig, 4 inches long. Nuclei in process of dissolution. Breadth of fibre 1/200 th. of an inch.

b. Fibre from the same pig, extending; remaining nuclei and granules separating. Breadth of fibre 1/1000 th. of an inch.

c. Fibre from a postnatal pig, 5 inches long. Nuclei not separated but persisting in their places. Breadth of fibre 1/100 th. of an inch, of lateral bands 1/1000 th. of an inch.

d. Fibre from a postnatal pig, 5 1/2 inches long, extending. Breadth of fibre 1/5000 th. of an inch, clusters of granules...
1/1000 th. of an inch apart.


Fig. 6. Fibre from a separate pig 3 1/2 inches long. Nuclei separated, striae visible; breadth of fibre 1/5000 th. of an inch.

Fig. 7. Fibre from a separate pig 8 inches long; showing the method of increase by external nuclei in various stages.

Fig. 8. Another fibre from the same specimen. Striae well marked. These fibres vary in diameter from 1/4000 to 1/3000 of an inch.

Figs. 9 and 10. Fibres from a pig at the period of birth.

Fig. 11. Fibre from a separate pig 5 inches long. Primary nuclei separating. Increase by external nuclei. Breadth of fibre 1/200 th. of an inch.
Plate II.

Fig. 1. From the back of a Frog Tadpole 1/2 inches in length. Illustrates the body being half an inch, and the tail 7/40ths of an inch long - at the junction of the tail with the body. Shows the original molecular blastema of muscle with the cytoplasm forming in it. These cytoplasm in the Frog Tadpole, Tadpole, Foetal calf, and Chick measure, on an average, 1/100 th. to 2/500 th. of an inch in length, and from 1/100 th. to 2/30 th. of an inch in breadth. The molecules vary in size from 1/500 th. of an inch in diameter to a size just perceptible by the eye.

Fig. 2. From the same Tadpole, and the same part of the body. Shows some of the cytoplasm isolated, and the effect of changing the focus, making them appear like oil globules.

Fig. 3. From a Frog Tadpole at the same part. Shows the cytoplasm, as they often are seen before they become broken up into clusters of granules, appearing enlarged, more spherical in shape, and their con...
texts multiplied.

d. Cytoblasts acted on by sulphuric ether, both isolated and embedded in the blastema.

c. Cytoblasts in the blastema, which are being dissolved.

Fig. 4. Muscular fibres from the anterior extremities of a Frog Tadpole, 1½ inches long. The anterior extremities not being developed as organs separate from the body but just beginning to make their appearance externally. The body of the animal measured 3/4ths of an inch in length; the posterior extremities each ½ an inch long.

a. Fibre 1/30th of an inch in breadth, showing the cytoblasts arranged in linear series, with their long axes in the direction of the fibre, and bounded by lateral bands.

b. A fibre, some of the cytoblasts of which are broken up into clusters of granules, and others are undergoing the process.

Fig. 5. Fibrellae of the muscle of a Frog Tadpole 1½ inches long and which has been about 60 hours in a weak solution of Chronic Acid. Shows the formation of the transverse striæ in the fibrellae by the arrangement in linear series of spherical globules connected together by blastema.
a. A fibrilla, $\frac{1}{450}$ of an inch in diameter, in which the so-called "clear spaces" by a near focus appear darker than those spaces which with a distant focus seem to be dark.

b. A slightly magnified view of a fibrilla showing the spherical character of the globular particles which become the so-called "clear spaces" of adult muscle.

c. The injunctive appearance of the blastema, to form the dark spaces separating the light globules, is present on one side only of the fibrilla in consequence of the direction in which the light falls on it.

d. Fibrioles so narrow that the distinctive characters of their particles are not apparent.

Fig. 6. From the same tadpole as the preceding figure; was 128 hours in a weak solution of Chromic Acid. The muscle was as soft as when fresh. It is an elementary Fasciculus or Primitive Muscle Fibre 1/500 th of an inch in diameter with its delicate sarcoleuma which is distinguished by the cytoplasm, connected with its formation, being more superficial than those of the fibre. Faint striæ are seen at the margins shining through the sheath.

Fig. 7. From the posterior extremities of a frog tadpole
\[\frac{4}{5}\text{ in. in length, which has been 4 days in a weak solution of Chronic Acid. A fasciculus or Primitive muscle fibre, the sarcomma of which is not so far developed as that of the preceding, being part of one of the lateral bands is distinct from the fibre; and the transverse striæ are more evident than in the preceding.}\]

Fig. 8. From the same specimen as figure 5. It represents a fasciculus dissected into fibres. It shows, also, the spherical character of the globular particles, their arrangement, and the effect of changing the focus on those in certain of the fibres. The fibres measure, on an average, \(\frac{1}{1600}\text{ th of an inch in diameter.}\)

Fig. 9. From the same specimen as figure 6. Shows two stages of the process of development taking place at the same time in the fibre. Towards the one end of the fibre is seen the longitudinal striation with dissolving cytoblasts. At the other extremity are transverse striæ appearing at the margins, with cytoblasts in the centre. Some of the cytoblasts appear to be lying on the surface, and are connected with
The formation of the sarcolerisma.

Fig. 10. A muscular fibre from the external intercostal muscles of a foetal calf 10½ inches long, showing the first appearance of transverse striation in the lateral bands; and the consolidation of the lateral bands with the central portion of the fibre which is occupied by the cytoplasts. The muscle was pink, unaffected by any reagent, and is cylindrical in form. The whole fibre, including the lateral bands is \( \frac{2730}{1000} \) th. of an inch in diameter, and the lateral bands are each \( \frac{1040}{1000} \) th. of an inch broad.

Fig. 11. From the muscles of the thigh of the same foetal. An elementary fasciculus displaying longitudinal striation of its substance, with two cytoplasts and the remains of others lying along its axis. This stage in development is speedily followed by that of commencement of transverse striation. The muscular fibres of the vertebrate at this stage resemble the fibres of the contractile substance of many Mollicae and Annulosa. Compare with Plate IV figs. 5, 6, 7. The muscle from which this fibre was dissected was 10 days in a weak solution of chronic acid.
Fig. 12. Muscular fibre from the anterior extremities of the same foetus. The fibre has one of its lateral bands separated from it by dissection. The lateral band possesses its own cytoblasts. In the fibre a delicate longitudinal striation is apparent, and it has a few cytoblasts while the rest are supplanted by clusters of granules. The lateral band on the opposite side has coalesced with the fibre. The fibre as a whole is \( \frac{1}{1000} \) of an inch in diameter; and the separated lateral band is \( \frac{1}{5250} \) of an inch broad. The fibre is in its fresh state; and the lateral band is one contributing to the increase in breadth of the fibre.

Fig. 13. From the anterior extremities of the same foetus. Represents a fibre \( \frac{1}{1000} \) of an inch in diameter; probably of slower development than any of the preceding, showing the longitudinal striation very distinctly, also the lateral bands, cytoblasts, and clusters of granules. The muscle was 10 days in a very weak solution of Chronic Acid.

Fig. 14. Muscular fibre from the tongue of the preceding foetus. The fibre is narrower than the preceding, being
of an inch in diameter, but similar in other respects to the muscle of other parts of the body. The muscle was 10 days in a very weak solution of chronic acid.

Fig. 15. Muscle of a bird a week old, which was soaked from 4½ days in a solution of chronic acid. It displays an elementary fasciculus broken up into fibres at its one extremity. There are no cytolasts observable, and the transverse strie of the fibre shine obscurely through the delicate sarcoleuca. In some of the separated fibres, the clear spaces appear as spherical globules, in others the dark spaces are indicated by dots along the one margin of the fibre, extending seemingly only to a limited distance across the fibres, and at the extremities of some the transverse markings are not seen at all because of their delicacy.

Fig. 16. Shows the fibrillation of the blasticum in the muscle of the thigh of a chick on the 13th day of incubation. The cytolasts are arranged in linear series and united laterally by delicate bands of blastica. The appearance represented is similar to that of the contractile substance of some of the Mediate with some of the Tendeurs.
Plate III.

Fig. 1. From the thigh of a Frog Tadpole 14/10 inches in length, the body being 9/10 of an inch long. It represents an elementary fibre or Primitive Fascicle with carmine. The bladder is of a beautiful mauve colour (somewhat lighter than the drawing) and presenting a granular character with dark spots in it. The cytoplasts, lying in the centre of the fibre with their long axes in a line with the longitudinal direction of the fibre, appear as oval globular bodies only slightly tinged with carmine. The muscle was soaked for half an hour in a strong ammoniacal solution of carmine, and then for 3 hours in glycerine before being put up.

Fig. 2. From the same specimen as the preceding, showing the cytoplasts further separated, with clusters of granules between. The fibre possesses also lateral bands which, however, are not fully displayed by this focus.

Fig. 3. From a Frog Tadpole 17/10 inches long, which lay for about 60 hours in a weak solution of chromic acid. The fibre was quite isolated. It shows towards its upper end lateral bands, with cytoplasts in the centre, and a few granules between them. Raising downwards
Transverse striæ are observed along the margins of the fibre which are more deeply tinged than the centre, and the cytoplasm are replaced by granules; at this portion the fibre the lateral bands have coalesced with the fibre. The muscle lay half an hour in an ammoniacal solution of carmine.

Fig. 4. From the same specimen as the preceding. Represents an Elementary fasciculus dissected into fibrillae which possess all the characters already repeatedly described. The drawing gives only a faint idea of the beauty of fibrillae thus tinged by carmine.

Fig. 5. From a specimen derived from the same frog tadpole as the preceding, and similarly prepared. Displays two isolated fibrillae tinged with carmine, and showing the spherical character of the globules which constitute the so called "clear spaces" of striped muscular fibre.

Fig. 6. From the same specimen as the preceding figure, showing the effect on the "clear spaces" of changing the focus.

Fig. 7. A very long fibrilla seen floating loosely in the field of the microscope.

Fig. 8. A group of elementary fibres from the muscle of the
Thigh of a human fetus at the 7th month. The primary fasciculus, projecting further out than the others, tinged like them with carmine, possesses faint lateral indications of the commencement of the formation of transverse striae at its proximate extremity, while at the other end the transverse striae are seen to pass quite across the fibre.

Fig. 9. Fully developed muscular fibre from the bird, tinged with carmine. Shows the sarcolumina and transverse striae fully formed.

Fig. 10. Transverse section of human adult muscle coloured by carmine.
B.

Fig. 1. A fibre \( \frac{1}{1000} \) th. of an inch in diameter. From a preparation made by Lockhart Clarke and Katzman striped muscle, lent me by Dr. Bennett. "Muscular fibre from back muscle fibre of human foetus \( \frac{1}{2} \) th. of an inch long, been some time in a weak solution of chromic acid." Shows a primitive fibre possessing cytoblasts arranged linearly and with their long axes coinciding with the longitudinal direction of the fibre; as also granules which are very numerous perhaps in consequence of certain of the cytoblasts having been dissolved by chromic acid.

Fig. 2. Muscular fibre from the same specimen as the preceding, showing portions of its lateral bands separated from the fibre at the lower end, which portions are of the same breadth as those adherent to the fibre. It possesses cytoblasts and granules like the preceding.

Fig. 3. Fibre \( \frac{1}{300} \) th. of an inch broad, from a preparation similarly procured: "Muscular fibre of human foetus 2nd-3rd month." It represents the cytoblasts breaking up into clusters of granules. The fibre is of the same breadth throughout its length.

Fig. 4. Muscular fibre from the same preparation.
as the preceding figure. Shows a distinct longitudinal striation of its substance, similar to that represented in Plate II, fig. 11.

Fig. 5. From the same specimen as the preceding. Muscular fibre, and presenting the first appearance of the transverse striae as delicate streaks along the margin of the fibre. This fibre also, shows a longitudinal striation of its substance.

Fig. 6. Muscular fibres in a specimen lent me by the preceding by Dr. Bennett: "Muscular Fibre of Fetus Digitorum, Profundus of Human Fetus 2nd-3rd month." The fibres show cytoplasts arranged linearly in their axes, with the remnants of broken-down cytoplasts between them.

The muscular fibres represented in figures 6 to 10 inclusive are derived from the same part of the body. In the case of muscle (as in that of the other tissues of the body) not only do the various fibres in the same muscle vary in their stages of development, but the various muscles differ as to the progress of the process in each.

Fig. 7. Fibre from the muscle of the arm of a foetus about the 4th month, (4½ inches long). It shows
the growth in breadth of primitive muscle fibres by means of lateral bands and their myoblasts, as was stated to be the case in the chick and other animals. In a human foetus at this time the muscles are perfectly formed, distinct, and surrounded by delicate fasciae, which separate them from each other.

Fig. 8. Fibre from the Deltoid muscle of a human foetus about the 5th month. The breadth of the fibre is less than that of the previous figure, because the lateral bands have coalesced with the fibre. It shows the transverse striæ to be fully formed but faint and close together. The foetus lay for some weeks in dilute alcohol.

Fig. 9. Muscular fibre from the arm of a human foetus about the 6th month (12½ inches long and 1½ lbs. in weight). Represents the transverse striæ broader, darker, and further separate than in the preceding fibre.

Fig. 10. Muscular fibre from the arm of a foetus at the 9th month. The fibre closely resembles that of insects as already mentioned. It is cylindrical and somewhat flattened in form, with distinct, smooth,
The transverse striæ are broader than the light spaces, and are bounded by clear dark lines like those in the muscle of the house fly. See Plate IV. fig. 12.

Fig. 11. Fibriæ from the muscle of the thigh of a foetus about the 4th month, (4½ inches long), which has been 5 days in a weak solution of chromic acid. In the broader fibrel the clear spaces appear as spherical globules connected together by blastœna, arranged linearly, and bounded by two lines. In the other fibrellas they are seen as spherical dots darker than the substance between them.

Fig. 12. Fibre from the intercostal muscles of a human foetus at the 9th month, tinged with carmine. It shows the cytoplasms of the sarcoloena lying on the surface of the fibre.
Plate IV.

Fig. 1. The cytoblasts, met with in the contractile substance parative anatomy of the common Polype (Acantharia), isolated. They of muscle or contract closely resemble those met with in the earlier stages of the substance of development of the striped muscular fibre of Radiata.

Fig. 2. Vertical section through the contractile substance of the same animal. It presents an appearance analogous to that of the second stage in development of the striped muscular fibre of vertebrates: - that in which the molecular blasticas is fibrillated and the cytoblasts are arranged in linear series to form fibres. Besides the cytoblasts there are an innumerable number of molecules, as in Plate II, fig. 16.

Fig. 3. The sarcode, or flesh of the common fresh water sponge (Spongilla flava). Showing cytoblasts of various sizes embedded in a molecular substance. The cytoblasts have the same characters as those of the Radiata; and the molecules are seen partly to be collected in clusters, while others are more or less isolated.

Fig. 4. The same as in the preceding figure, acted.

Protozoa.
on by Acetic Acid. Showing the sarcoiJ elements Effect of Acetic
to be more transparent; the chlorophyll granules acid on Sarcode
dissolved; the contents of the cystoblasts very evident
from their walls seeming to have dissolved; and the
molecules of the blastema more distinct than formerly.

Fig. 5. Muscular fibres of Limpet. (Patella). The fibres
have a bluish, glistening appearance like ligamentar
tissues in the vertebrates. They are analogous to
the striped muscular fibres of the vertebrates immediately
before the first appearance of transverse strike in
them.

Fig. 6. Muscular fibres of Mussel. (Mytilus edulis), having
the same characters as those of the Limpet. The fibres
lie parallel to one another in the muscle, but do not
seem to be collected together in bundles and enclosed in
a sheath or sarcolemna.

Fig. 7. Muscular fibres of Slug (Limax). "Portion of
the retractile muscle of the tentacle in Limax." * After Lebert.

The muscle of the Mollusca closely resembles, when ex-
amined by the naked eye, the ligamentous tissue of
the vertebrates. The fibres of the muscle of Mollusca are
flattened cylinders, with a distinct longitudinal striation.
They run parallel to one another, and are grouped into

Mollusca
(Posebrancliata)

Mollusca
(Aniphenata)
Ibid. Page 216.
bundles or fasciculi, being connected together by a transparent, granular, intermediary substance, best seem to be enclosed in no sarcomema or sheath. They possess no cytoplasts, but many of them have a distinctly granular aspect, like the developing fibres of vertebrate striped muscle, the cytoplasts of which have been dissolved.

Fig. 8. Fibre from muscle of Leech (Annelida haemoglophila). "Muscular cylinder of the Leech." It presents very delicate striæ passing across the fibre which I consider to be only superficial foldings of or striæ on the sheath or sarcomema encasing the muscular fasciculi; and, therefore, they are not analogous to the true transverse striæ met with in the muscle of vertebrate animals.

Fig. 9. Muscular fibres of worm (Lumbricus terrestris). b, c, d, and e represent fibres in the fresh state, possessing transverse striation which is sarcomematous. b, c, d, and e are smaller fibres or filaments into which fasciculi like b and c may be dissected after the muscle has been 607 days in a weak solution of chromic acid, and which show no evidence
Ibid. Page 216.
whatever of transverse striæ.

Fig. 10. Muscular fasciculus from thigh of Shrimp, (Eragi bulgarus), with projecting fibrilla. It is observed to possess true, well-marked transverse striæ, the dark spaces being comparatively broader than in the muscles of most animals. The fibrilla, as well as the fasciculus, is seen to have these characters.

Fig. 11. Fibres from muscle of the Wild Bee, (Bombby Hera). "Muscular cylinders of Bombby Hera.

a. Primitive fibres.

b. Interior of a cylinder, the sheath having been raised."

The fibrillæ, Lebert describes, as containing molecular granules which are spherical. And the appearance in the drawing closely resembles that of the earliest forms of transverse striæ, in the striped muscle of the vertebrata. Compare these fibrillæ with those represented in Plate II. fig. 5. B.

Fig. 12. Muscular fasciculus and fibrilla from thigh of the common Housefly, (Musca Domestica). In this form of muscle the transverse striæ are most beautifully defined by a narrow, distinct, dark line at the margins of the dark spaces; which with a
certain focus appear as lines subdividing the light spaces. The clear spaces in the fibres, it will be noticed, though quadrilateral are not truly square-shaped as in the vertebrates, but are rather in the form of parallelograms; that is, they present a shape intermediate between the spherical and the square.

This fasciculus has an appearance very like the fasciculi of human striped muscle in a foetus of the 9th month. Compare with Plate III. B, fig. 10.

Fig. 13. Muscle of Cod, (Morrhua Bulparsi). The fasciculus is bounded by broader and darker margins than are usually found in most forms of muscle; which is probably owing both to its sarcolemma being thicker and to its being more of a cylindrical form.

a. and b. Fibres possessing dark and clear particles of a square form.

Fig. 14. Muscular fasciculi of Haddock, (Morrhua Ogalefins).

Vertebrata

(Pisces).

(Gadidae).

Fig. 15. Fasciculus with a projecting fibre from the Muscle of the Water-Hound, (Triton Aquaticus).

(Amphibia).

(Salamandridae).
Fig. 16. Muscle of the "Serin des canaries, (Fringilla canariensis)."

a. "Cylinders, showing clearly the transverse markings" (Fringillidae).

b. "Compound cylinder, showing the primitive cylinders." *

Fig. 17. Muscular fasciculus from Hedgehog, (Erinaceus Europaeus). The transverse markings in the muscle of this animal are broad, and so appear coarse.

Fig. 18. Fasciculus from the striped muscle of Ox, (Bos Taurus), representing the appearance which used formerly to be considered as characterising muscle in the state of contraction.
Description of Specimens.

This series of specimens is intended to confirm the views brought forward in the above paper by showing that the same phenomena take place in the case of the chick as in that of the other vertebrates already referred to, during the process of development of striped muscular fibre.

Specimen 1.

Shows the molecular blastema with the cyto blasts forming in it, this being the earliest form of voluntary muscle. It is derived from the skin of a chick one inch long, which has been 5 days in a very weak solution of chromic acid.

Specimen 2.

Shows the splitting up of the molecular blastema and linear arrangement of the cyto blasts to form fibres, in muscle, from the back of the same chick. This being the second stage in the process of development of muscle.

Specimen 3.

Illustrates the 3rd stage in development; viz. muscle in the form of elementary fibres with lateral bands and cyto blasts in their centres. It shows muscle in the fresh state from the
thigh of a chick, 3 inches long. Thus it is seen that the development of muscle is not proportionate to the growth of the animal as a whole.

Specimen d.
The fibres are those of muscle from the thigh of a chick 3½ inches long. They possess longitudinal striation which marks the 4th stage in the development of muscular fibres and indicates the splitting up of the elementary fasciculi into fibrillae. The specimen is derived from muscle in the fresh state.

Specimen e.
Along the margins of some of the fibres is seen the earliest appearance of the transverse striare, whilst in others of the fibres the process of transverse striation is seen to be completed and the transverse striare pass quite across the fibre. This specimen, illustrating the 5th stage in the process of development, is derived from the same chick as the preceding one.

Specimen f.
Shows Elementary Fasciculi or Primitive Muscle-fibres teased out into their constituent Fibrillae, in which
the transverse strie of the fibrillae are seen to be composed of spherical globules connected together in linear series by sarcomous substance. Got from a Frog Tadpole 1½ inches in length which lay for about a week in a weak solution of chronic acid. Specimen g.

Shows the last stage in the process of development, during which the sarcolumen makes its appearance and many of the fibres exhibit the sarcolinematos-forming cytolast lying on their surface. It is a fresh specimen derived from the thigh of a chicken which has newly burst its egg.

Specimen h.

Fresh muscular fibres from the leg of a bird nearly a week old showing their relation with the nerves.

Specimen i.

Specimens i, i', and m. show the development of Human striated muscular fibre during the latter months of foetal life. Specimen h. from the muscles of the thigh of a foetus at the 4½ months (4½ inches long) represents fibres with cytolasts and their transverse strie more or less fully formed.

Specimen k.

From the Back of a 5½ month foetus which has been...
preserved for a few weeks in dilute alcohol. The fibres differed very slightly from those of the preceding specimen, being only more perfect in their transverse striation.

**Specimen I.**

Muscular fibres from the superior extremity of a human foetus of the 6th month (12 1/2 inches long and 1/2 lbs. in weight).

**Specimen II.**

Consists of muscular fibres derived from the arm of a human foetus at the 9th month, the transverse striæ of which present an appearance closely similar to that of the muscle of the house-fly.