Croonian Lecture
Mr. Carlisle Novr. 8. 1804.

L.

PHILOSOPHICAL

TRANSACTIONS.

I. *The Croonian Lecture on muscular Motion. By* Anthony Carlisle, *Esq. F. R. S.*

Read November 8, 1804.

Animal physiology has derived several illustrations and additions, from the institution of this Lecture on muscular Motion; and the details of anatomical knowledge have been considerably augmented by descriptions of muscular parts before unknown.

Still, however, many of the phenomena of muscles remain unexplained, nor is it to be expected that any sudden insulated discovery shall solve such a variety of complicated appearances.

Muscular motion is the first sensible operation of animal life: the various combinations of it sustain and carry on the multiplied functions of the largest animals: the temporary cessation of this motive faculty is the suspension of the living powers, its total quiescence is death.

By the continuance of patient, well directed researches, it is reasonable to expect much important evidence on this subject;

and, from the improved state of collateral branches of knowledge, together with the addition of new sources, and methods of investigation, it may not be unreasonable to hope for an ultimate solution of these phenomena, no less complete, and consistent, than that of any other desideratum in physical science.

The present attempt to forward such designs is limited to circumstances which are connected with muscular motion, considered as causes, or rather as a series of events, all of which contribute, more or less, as conveniences, or essential requisites, to the phenomena; the details of muscular applications being distinct from the objects of this lecture.

No satisfactory explanation has yet been given of the state or changes which obtain in muscles during their contractions or relaxations, neither are their corresponding connections with the vascular, respiratory, and nervous systems, sufficiently traced. These subjects are therefore open for the present enquiry, and although I may totally fail in this attempt to elucidate any one of the subjects proposed, nevertheless I shall not esteem my labour useless, or the time of the Royal Society altogether unprofitably consumed, if I succeed in pointing out the way to the future attainment of knowledge so deeply interesting to mankind.

The muscular parts of animals are most frequently composed of many substances, in addition to those which are purely muscular. In this gross state, they constitute a flexible, compressible solid, whose texture is generally fibrous, the fibres being compacted into fasciculi, or bundles of various thickness. These fibres are elastic during the contracted state of muscles after death, being capable of extension to more than one-fifth of their length, and of returning again to their former state of contraction.

This elasticity, however, appears to belong to the enveloping reticular or cellular membrane, and it may be safely assumed that the intrinsic matter of muscle is not elastic.

The attraction of cohesion, in the parts of muscle, is strongest in the direction of the fibres, it being double that of the contrary, or transverse direction.

When muscles are capable of reiterated contractions and relaxations, they are said to be alive, or to possess irritability. This quality fits the organ for its functions. Irritability will be considered, throughout the present lecture, as a quality only.

When muscles have ceased to be irritable, their cohesive attraction in the direction of their fibres is diminished, but it remains unaltered in the transverse direction.

The hinder limbs of a frog attached to the pelvis being stripped of the skin, one of them was immersed in water at 115° of Fahrenheit, during two minutes, when it ceased to be irritable. The thigh bones were broken in the middle, without injuring the muscles, and a scale affixed to the ancle of each limb: a tape passed between the thighs was employed to suspend the apparatus. Weights were gradually introduced into each scale, until, with five pounds avoirdupois, the dead thigh was ruptured across the fleshy bellies of its muscles.

The irritable thigh sustained six pounds weight avoirdupois, and was ruptured in the same manner. This experiment was repeated on other frogs, where one limb had been killed by a watery solution of opium, and on another where essential oil of cherry laurel* was employed: in each experiment, the

* Distilled oil from the leaves of the *Prunus Laurocerasus.*

irritable limb sustained a weight one-sixth heavier than the dead limb.

It may be remarked, in confirmation of these experiments, that when muscles act more powerfully, or more rapidly, than is equal to the strength of the sustaining parts, they do not usually rupture their fleshy fibres, but break their tendons, or even an intervening bone, as in the instances of ruptured tendo Achillis, and fractured patella. Instances have however occurred, wherein the fleshy bellies of muscles have been lacerated by spasmodic actions; as in tetanus the recti abdominis have been torn asunder, and the gastrocnemii in cramps; but in those examples it seems that either the antagonists produce the effect, or the over-excited parts tear the less excited in the same muscle. From whence it may be inferred, that the attraction of cohesion in the matter of muscle is considerably greater during the act of contracting, than during the passive state of tone, or irritable quiescence, a fact which has been always assumed by anatomists from the determinate forces which muscles exert.

The muscular parts of different classes of animals vary in colour and texture, and not unfrequently those variations occur in the same individual.

The muscles of fishes and vermes are often colourless, those of the mammalia and birds being always red: the amphibia, the accipenser, and squalus genera, have frequently both red and colourless muscles in the same animal.

Some birds, as the black game,* have the external pectoral muscles of a deep red colour, whilst the internal are pale.

In texture, the fasciculi vary in thickness, and the reticular

* *Tetrao tetrix*, LIN.

membrane is in some parts coarse, and in others delicate: the heart is always compacted together by a delicate reticular membrane, and the external glutæi by a coarser species.

An example of the origin of muscle is presented in the history of the incubated egg, but whether the rudiments of the punctum saliens be part of the cicatricula organised by the parent, or a structure resulting from the first process of incubation, may be doubtful: the little evidence to be obtained on this point seems in favour of the former opinion; a regular confirmation of which would improve the knowledge of animal generation by shewing that it is gemmiferous. There are sufficient analogies of this kind in nature, if reasoning from analogies were proper for the present occasion.

The punctum saliens, during its first actions, is not encompassed by any fibres discoverable with microscopes, and the vascular system is not then evolved, the blood flowing forwards, and backwards, in the same vessels. The commencement of life in animals of complex structure is, from the preceding fact, like the ultimate organization of the simpler classes.

It is obvious that the muscles of birds are formed out of the albumen ovi, the vitellus, and the atmospheric air, acted upon by a certain temperature. The albumen of a bird's egg is wholly consumed during incubation, and the vitellus little diminished, proving that the albumen contains the principal elementary materials of the animal thus generated; and it follows that the muscular parts, which constitute the greater proportion of such animals when hatched, are made out of the albumen, a small portion of the vitellus, and certain elements, or small quantities of the whole compound of the atmosphere.

The muscles of birds are not different, in any respect, from those of quadrupeds of the class of mammalia.

The anatomical structure of muscular fibres is generally complex, as those fibres are connected with membrane, blood-vessels, nerves, and lymphæducts; which seem to be only appendages of convenience to the essential matter of muscle.

A muscular fibre, duly prepared by washing away the adhering extraneous substances, and exposed to view in a powerful microscope, is undoubtedly a solid cylinder, the covering of which is reticular membrane, and the contained part a pulpy substance irregularly granulated, and of little cohesive power when dead.

A difficulty has often subsisted among anatomists concerning the ultimate fibres of muscles; and, because of their tenuity, some persons have considered them infinitely divisible, a position which may be contradicted at any time, by an hour's labour at the microscope.

The arteries arboresce copiously upon the reticular coat of the muscular fibre, and in warm-blooded animals these vessels are of sufficient capacity to admit the red particles of blood, but the intrinsic matter of muscle, contained within the ultimate cylinder, has no red particles.

The arteries of muscles anastomose with corresponding veins; but this course of a continuous canal cannot be supposed to act in a direct manner upon the matter of muscle.

The capillary arteries terminating in the muscular fibre must alone effect all the changes of increase in the bulk, or number, of fibres, in the replenishment of exhausted materials, and in the repair of injuries; some of these necessities may be supposed to be continually operating. It is well known, that the circulation of the blood is not essential to muscular action; so that the mode of distribution of the blood vessels, and the differences in their size, or number, as applied to muscles, can only be adaptations to some special convenience.

Another prevalent opinion among anatomists, is the infinite extension of vascularity, which is contradicted in a direct manner by comparative researches. The several parts of a quadruped are sensibly more or less vascular, and of different contextures; and, admitting that the varied diameter of the blood vessels disposed in each species of substance, were to be constituted by the gross sensible differences of their larger vessels only, yet, if the ultimate vessels were in all cases equally numerous, then the sole remaining cause of dissimilarity would be in the compacting of the vessels. The vasa vasorum of the larger trunks furnish no reason, excepting that of a loose analogy, for the supposition of vasa vasorum extended without limits. Moreover, the circulating fluids of all animals are composed of water, which gives them fluidity, and of animalised particles of defined configuration and bulk; it follows that the vessels through which such fluids are to pass, must be of sufficient capacity for the size of the particles, and that smaller vessels could only filtrate water devoid of such animal particles: a position repugnant to all the known facts of the circulation of blood, and the animal economy.

The capillary arteries which terminate in the muscular fibre, must be secretory vessels for depositing the muscular matter, the lymphæducts serving to remove the superfluous extravasated watery fluids, and the decayed substances which are unfit for use.

The lymphæducts are not so numerous as the blood vessels, and certainly do not extend to every muscular fibre: they appear to receive their contained fluids from the intersticial spaces formed by the reticular or cellular membrane, and not from the projecting open ends of tubes, as is generally represented. This mode of receiving fluids out of a cellular structure, and conveying them into cylindrical vessels, is exemplified in the corpora cavernosa, and corpus spongiosum penis, where arterial blood is poured into cellular or reticular cavities, and from thence it passes into common veins by the gradual coarctation of the cellular canals.

In the common green turtle, the lacteal vessels universally arise from the loose cellular membrane, situated between the internal spongy coat of the intestines and the muscular coat. The cellular structure may be filled from the lacteals, or the lacteals from the cellular cavities. When injecting the smaller branches of the lymphæducts retrograde in an œdematous human leg, I saw, very distinctly, three orifices of these vessels terminating in the angles of the cells, into which the quicksilver trickled. The preparation is preserved, and a drawing of the appearance made at the time. It was also proved, by many experiments, that neither the lymphæducts, nor the veins, have any valves in their minute branches.

The nerves of voluntary muscles separate from the same bundles of fibrils with the nerves which are distributed in the skin, and other parts, for sensation; but a greater proportion of nerve is appropriated to the voluntary muscles, than to any other substances, the organs of the senses excepted.

The nerves of volition all arise from the parts formed by the junction of the two great masses of the brain, called the Cerebrum and Cerebellum, and from the extension of that substance throughout the canal of the vertebræ. Another class of muscles, which are not subject to the will, are supplied by peculiar nerves; they are much smaller, in proportion to the bulk of the parts on which they are distributed, than those of the voluntary muscles; they contain less of the white opaque medullary substance than the other nerves, and unite their fibrils, forming numerous anastomoses with all the other nerves of the body, excepting those appropriated to the organs of the senses. There are enlargements at several of these junctions, called Ganglions, and which are composed of a less proportion of the medullary substance, and their texture is firmer than that of ordinary nerves.

The terminal extremities of nerves have been usually considered of unlimited extension; by accurate dissection however, and the aid of magnifying glasses, the extreme fibrils of nerves are easily traced as far as their sensible properties, and their continuity extends. The fibrils cease to be subdivided whilst perfectly visible to the naked eye, in the voluntary muscles of large animals, and the spaces they occupy upon superficies where they seem to end, leave a remarkable excess of parts unoccupied by those fibrils. The extreme fibrils of nerves lose their opacity, the medullary substance appears soft and transparent, the enveloping membrane becomes pellucid, and the whole fibril is destitute of the tenacity necessary to preserve its own distinctness; it seems to be diffused and mingled with the substances in which it ends. Thus the ultimate terminations of nerves for volition, and ordinary sensation, appear to be in the reticular membrane, the common covering of all the different substances in an animal body, and the connecting medium of all dissimilar parts.

By this simple disposition, the medullary substance of nerve is spread through all organized, sensible, or motive parts, forming a continuity which is probably the occasion of sympathy. Peculiar nerves, such as the first and second pairs, and the portio mollis of the seventh, terminate in an expanse of medullary substance which combines with other parts and membranes, still keeping the sensible excess of the peculiar medullary matter.

The peculiar substance of nerves must in time become inefficient; and, as it is liable to injuries, the powers of restoration, and repair, are extended to that material. The reunion of nerves after their division, and the reproduction after part of a nerve has been cut away, have been established by decisive experiments. Whether there is any new medullary substance employed to fill up the break, and, if so, whether the new substance be generated at the part, or protruded along the nervous theca from the brain, are points undetermined: the history of the formation of a fœtus, the structure of certain monsters, and the organization of simple animals, all seem to favour the probability, that the medullary matter of nerves is formed at the parts where it is required, and not in the principal seat of the cerebral medulla.

This doctrine, clearly established, would lead to the belief of a very extended commixture of this peculiar matter in all the sensible and irritable parts of animals, leaving the nerves in their limited distribution, the simple office of conveying impressions from the two sentient masses with which their extremities are connected. The most simple animals in whom no visible appearances of brain or nerves are to be found, and no fibrous arrangement of muscles, may be considered of this description: Mr. John Hunter appeared to have had some incomplete notions upon this subject, which may be gathered from his representation of a materia vitæ in his Treatise on the Blood, &c. Perhaps it would be more proper to distinguish the peculiar matter of muscle by some specific term, such, for example, as materia contractilis.

A particular adaptation for the nerves which supply the electrical batteries of the torpedo, and gymnotus, is observable, on the exit of each from the skull; over which there is a firm cartilage acting as a yoke, with a muscle affixed to it, for the obvious purpose of compression: so that a voluntary muscle probably governs the operations of the battery.

The matter of the nerves, and brain, is very similar in all the different classes of animals.

The external configuration of animals is not more varied than their internal structure.

The bulk of an animal, the limitation of its existence, the medium in which it lives, and the habits it is destined to pursue, are each, and all of them, so many indications of the complexity or simplicity of their internal structure. It is notorious that the number of organs, and of members, is varied in all the different classes of animals; the vascular and nervous systems, the respiratory, and digestive organs, the parts for procreation, and the instruments of motion, are severally varied, and adapted to the condition of the species. This modification of anatomical structure is extended in the lowest tribes of animals, until the body appears to be one homogeneous substance. The cavity for receiving the food is indifferently the internal, or external surface, for they may be inverted, and still continue to digest food; the limbs or tentacula may be cut off, and they will be regenerated without apparent inconvenience to the individual: the whole animal is equally sensible, equally irritable, equally alive: its procreation is gemmiferous. Every part is pervaded by the nutritious juices, every part is acted upon by the respiratory influence, every part is equally capable of motion, and of altering its figure in all directions, whilst neither blood-vessels, nerves, nor muscular fibres, are discoverable by any of the modes of investigation hitherto instituted.

From this abstract animal (if such a term may be admitted) up to the human frame, the variety of accessory parts, and of organs by which a complicated machinery is operated, exhibit infinite marks of design, and of accommodations to the purposes which fix the order of nature.

In the more complicated animals, there are parts adapted for trivial conveniences, much of their materials not being alive, and the entire offices of some liable to be dispensed with. The water transfused throughout the intersticial spaces of the animal fabric, the combinations with lime in bones, shells, and teeth; the horns, hoofs, spines, hairs, feathers, and cuticular coverings, are all of them, or the principal parts of their substance, extra-vascular, insensible, and unalterable by the animal functions after they are completed. I have formed an opinion, grounded on extensive observation, that many more parts of animal bodies may be considered as inanimate substances; even the reticular membrane itself seems to be of this class, and tendons, which may be the condensed state of it; but these particulars are foreign to the present occasion.

The deduction now to be made, and applied to the history of muscular motion, is, that animated matter may be connected with inanimate; this is exemplified in the adhesions of the muscles of multi-valve, and bi-valve shell fish, to the inorganic shell, the cancer Bernhardus to the dead shells of other animals, and in the transplantation of teeth. All of which, although somewhat contrary to received opinion, have certainly no degree of vascularity, or vital connection with the inhabitant; these shells being liable to transudations of cupreous salts and other poisonous substances, whilst the animal remains uninjured. A variety of proofs to the same effect might be adduced, but it would be disrespectful to this learned Body to urge any farther illustrations on a subject so obvious.

The effects of subdivision, or comminution of parts among the complicated organized bodies, is unlike that of mineral bodies: in the latter instance, the entire properties of the substance are retained, however extensive the subdivision; in the former substances, the comminution of parts destroys the essential texture and composition, by separating the gross arrangements of structure upon which their specific properties depend. From similar causes it seems to arise, that animals of minute bulk are necessarily of simple structure: size alone is not, however, the sole cause of their simple organization, because examples are sufficiently numerous wherein the animal attains considerable bulk, and is of simple structure, and *vice versâ*: but, in the former, the medium in which they live, and the habits they assume, are such as do not require extensive appendages, whilst the smaller complex animals are destined to more difficult, and more active exertions. It may be assumed however, as an invariable position, that the minutest animals are all of simple organization.

Upon a small scale, life may be carried on with simple materials; but the management, and provisions for bulky animals, with numerous limbs, and variety of organs, and appendages of convenience, are not effected by simple apparatus; thus, the skeleton which gives a determinate figure to the species, supports its soft parts, and admits of a geometrical motion, is placed interiorly, where the bulk of the animal admits of the bones being sufficiently strong, and yet light enough for the moving powers; but the skeleton is placed externally, where the body is reduced below a certain magnitude, or where the movements of the animal are not to be of the floating kind: in which last case the bulk is not an absolute cause. The examples of testaceous vermes, and coleopterous, as well as most other insects, are universally known.

The opinion of the muscularity of the crystalline lens of the eye, so ingeniously urged by a learned member of this Society, is probably well founded; as the arrangement of radiating lines of the matter of muscle, from the centre to the circumference of the lens, and these compacted into angular masses, would produce specific alterations in its figure.

This rapid sketch of the history of muscular structure has been obtruded before the Royal Society to introduce the principal experiments, and reasonings which are to follow: they are not ordered with so much exactness as becomes a more deliberate essay, but the intention already stated, and the limits of a lecture are offered as the apology.

Temperature has an essential influence over the actions of muscles, but it is not necessary that the same temperature should subsist in all muscles during their actions; neither is it essential that all the muscular parts of the same animal should be of uniform temperatures for the due performance of the motive functions.

It appears that all the classes of animals are endowed with some power of producing thermometrical heat, since it has been so established in the amphibia, pisces, vermes, and insecta, by Mr. John Hunter; a fact which has been verified to my own experience; the term "cold-blooded" is therefore only relative. The ratio of this power is not, however, in these examples, sufficient to preserve their equable temperature in cold climates, so that they yield to the changes of the atmosphere, or the medium in which they reside, and most of them become torpid, approaching to the degree of freezing water. Even the mammalia, and aves, possess only a power of resisting certain limited degrees of cold; and their surfaces, as well as their limbs, being distant from the heart, and principal blood-vessels, the muscular parts so situated are subject to considerable variations in their temperature, the influence of which is known.

In those classes of animals which have little power of generating heat, there are remarkable differences in the structure of their lungs, and in the composition of their blood, from the mammalia and aves.

Respiration is one of the known causes which influences the temperatures of animals: where these organs are extensive, the respirations are performed at regular intervals, and are not governed by the will, the whole mass of blood being exposed to the atmosphere in each circulation. In all such animals living without the tropics, their temperature ranges above the ordinary heat of the atmosphere, their blood contains more of the red particles than in the other classes, and their muscular irritability ceases more rapidly after violent death.

The respirations of the animals denominated "cold-blooded," are effected differently from those of high temperature; in some of them, as the amphibia of LINNÆUS, the lungs receive atmospheric air, which is arbitrarily retained in large cells, and not alternately, and frequently changed. The fishes, and the testaceous vermes, have lungs which expose their blood to water, but whether the water alone, or the atmospheric air mingled with it, furnish the changes in the pulmonary blood, is not known.

In most of the genera of insects, the lungs are arborescent tubes containing air, which, by these channels, is carried to every vascular part of the body. Some of the vermes of the simpler construction have no appearance of distinct organs, but the respiratory influence is nevertheless essential to their existence, and it seems to be effected on the surface of the whole body.

In all the colder animals, the blood contains a smaller proportion of the red colouring particles than in the mammalia, and aves; the red blood is limited to certain portions of the body, and many animals have none of the red particles.

The following animals were put into separate glass vessels, each filled with a pound weight of distilled water, previously boiled to expel the air, and the vessels inverted into quicksilver; *viz.* one gold fish, one frog, two leeches, and one fresh-water muscle.* These animals were confined for several days, and exposed to the sun in the day time, during the month of January, the temperature being from 43° to 48°, but no air bubbles were produced in the vessels, nor any sensible diminution of the water. The frog died on the third day, the fish on the fifth, the leeches on the eighth, and the fresh-water

* *Mytilus Anatinus.*

muscle on the thirteenth. This unsuccessful experiment was made with the hope of ascertaining the changes produced in water by the respiration of aquatic animals, but the water had not undergone any chemical alteration.

Animals of the class mammalia which hybernate, and become torpid in the winter, have at all times a power of subsisting under a confined respiration, which would destroy other animals not having this peculiar habit. In all the hybernating mammalia there is a peculiar structure of the heart, and its principal veins; the superior cava divides into two trunks; the left, passing over the left auricle of the heart, opens into the inferior part of the right auricle, near to the entrance of the vena cava inferior. The veins usually called azygos, accumulate into two trunks, which open each into the branch of the vena cava superior, on its own side of the thorax. The intercostal arteries and veins in these animals are unusually large.

This tribe of quadrupeds have the habit of rolling up their bodies into the form of a ball during ordinary sleep, and they invariably assume the same attitude when in the torpid state: the limbs are all folded into the hollow made by the bending of the body; the clavicles, or first ribs, and the sternum, are pressed against the fore part of the neck, so as to interrupt the flow of blood which supplies the head, and to compress the trachea: the abdominal viscera, and the hinder limbs are pushed against the diaphragm, so as to interrupt its motions, and to impede the flow of blood through the large vessels which penetrate it, and the longitudinal extension of the cavity of the thorax is entirely obstructed. Thus a confined circulation of the blood is carried on through the heart, probably adapted to the last weak actions of life, and to its gradual recommencement.

This diminished respiration is the first step into the state of torpidity; a deep sleep accompanies it; respiration then ceases altogether; the animal temperature is totally destroyed, coldness and insensibility take place, and finally the heart concludes its motions, and the muscles cease to be irritable. It is worthy of remark that a confined air, and a confined respiration, ever precede these phenomena: the animal retires from the open atmosphere, his mouth and nostrils are brought into contact with his chest, and enveloped in fur; the limbs become rigid, but the blood never coagulates during the dormant state. On being roused, the animal yawns, the respirations are fluttering, the heart acts slowly and irregularly, he begins to stretch out his limbs, and proceeds in quest of food. During this dormancy, the animal may be frozen, without the destruction of the muscular irritability, and this always happens to the garden snail,* and to the chrysalides of many insects during the winter of this climate.

The loss of motion and sensation from the influence of low temperature, accompany each other, and the capillaries of the vascular system appear to become contracted by the loss of animal heat, as in the examples of numbness from cold. Whether the cessation of muscular action be owing to the impeded influence of the nerves, or to the lowered temperature of the muscles themselves, is doubtful; but the known influence of cold upon the sensorial system, rather favours the supposition that a certain temperature is necessary for the transmission of nervous influence, as well as sensation.

* *Helix nemoralis.*

The hybernating animals require a longer time in drowning than others. A full grown hedge-hog was submersed in water at 48°, and firmly retained there; air-bubbles began instantly to ascend, and continued during four minutes; the animal was not yet anxious for its liberty. After seven minutes it began to look about, attempting to escape; at ten minutes it rolled itself up, only protruding the snout, which was hastily retracted on being touched with the finger, and even the approach of the finger caused it to retract. After fifteen minutes complete submersion, the animal still remained rolled up, and withdrew its nose on being touched. After remaining thirty minutes under water, the animal was laid upon flannel, in an atmosphere of 62°, with its head inclined downwards; it soon began to relax the sphincter muscle which contracts the skin, slow respirations commenced, and it recovered entirely, without artificial aid, after two hours. Another hedge-hog submersed in water at 94°, remained quiet until after five minutes; about the eighth minute it stretched itself out, and expired at the tenth. It remained relaxed, and extended, after the cessation of the vital functions; and its muscles were relaxed, contrary to those of the animal drowned in the colder water.

The irritability of the heart is inseparably connected with respiration. Whenever the inhaled gas differs in its properties from the common atmosphere, the muscular and sensible parts of the system exhibit the change: the actions of the heart are altered or suspended, and the whole muscular and sensorial systems partake of the disorder: the temperature of animals, as before intimated, seems altogether dependant on the respiratory functions, although it still remains uncertain in what manner this is effected.

The blood appears to be the medium of conveying heat to the different parts of the body; and the changes of animal temperature in the same individual at various times, or in its several parts, are always connected with the degree of rapidity of the circulation. It is no very wide stretch of physiological deduction to infer, that this increased temperature is produced by the more frequent exposure of the mass of blood to the respiratory influence, and the short time allowed in each circuit for the loss of the acquired heat.

The blood of an animal is usually coagulated immediately after death, and the muscles are contracted; but, in some peculiar modes of death, neither the one, nor the other of these effects are produced: with such exceptions, the two phenomena are concomitant.

A preternatural increase of animal heat delays the coagulation of the blood, and the last contractions of the muscles: these contractions gradually disappear, before any changes from putrefaction are manifested; but the cup in the coagulum of blood does not relax in the same manner; hence it may be inferred, that the final contraction of muscles is not the coagulation of the blood contained in them; neither is it a change in the reticular membrane, nor in the blood-vessels, because such contractions are not general throughout those substances. The coagulation of the blood is a certain criterion of death. The reiterated visitations of blood are not essential to muscular irritability, because the limbs of animals, separated from the body, continue for a long time afterwards capable of contractions, and relaxations.

The constituent elementary materials of which the peculiar animal and vegetable substances consist, are not separable by any chemical processes hitherto instituted, in such manner as to allow of a recombination into their former state. The composition of these substances appears to be naturally of transient duration, and the attractions of the elementary materials which form the gross substances, are so loose and unsettled, that they are all decomposed without the intervention of any agent, merely by the operation of their own elementary parts on each other.

An extensive discussion of the chemical properties attaching to the matter of muscle would be a labour unsuited to this occasion; I should not, however, discharge my present duty, if I omitted to say, that all such investigations can only be profitable when effected by simple processes, and when made upon the raw materials of the animal fabric, such, perhaps, as the albumen of eggs, and the blood. But, until by synthetical experiments the peculiar substances of animals are composed from what are considered to be elementary materials, or the changes of organic secretion imitated by art, it cannot be hoped that any determinate knowledge should be established upon which the physiology of muscles may be explained. Such researches and investigations promise, however, the most probable ultimate success, since the phenomena are nearest allied to those of chemistry, and since all other hypotheses have, in their turns, proved unsatisfactory.

Facts and Experiments tending to support and illustrate the preceding Argument.

An emaciated horse was killed by dividing the medulla spinalis, and the large blood-vessels under the first bone of the sternum.

The temperature of the flowing blood was		103°
	Spleen - -	103
	Stomach - -	101
	Colon - -	98
	Bladder of urine	97
	Atmosphere -	30.

Three pigs, killed by a blow on the head, and by the immediate division of the large arteries and veins, entering the middle of the basis of the heart, had the blood flowing from these vessels of 106, 106½, and 107°; the atmospheric temperature being at 31°.

An ox, killed in a similar manner, the blood 103°; atmosphere 50°.

Three sheep, killed by dividing the carotid arteries, and internal jugular veins: their blood 105, 105, 105½°; atmosphere 41°.

Three frogs, kept for many days in an equable atmosphere at 54°; their stomachs 62°.

The watery fluid issuing from a person tapped for dropsy of the belly 101°: the atmosphere being 43°, and the temperature of the superficies of the body at 96°.

These temperatures are considerably higher than the common estimation.

A man's arm being introduced within a glass cylinder, it was duly closed at the end which embraced the head of the humerus; the vessel being inverted, water at 97° was poured in, so as to fill it. A ground brass plate closed the lower aperture, and a barometer tube communicated with the water at the bottom of the cylinder. This apparatus including the arm, was again inverted, so that the barometer tube became a gage, and no air was suffered to remain in the apparatus. On the slightest action with the muscles of the hand, or fore-arm, the water ascended rapidly in the gage, making librations of six and eight inches length in the barometer tube, on each contraction and relaxation of the muscles.

The remarkable effects of crimping fish by immersion in water, after the usual signs of life have disappeared, are worthy attention; and whenever the rigid contractions of death have not taken place, this process may be practised with success. The sea fish destined for crimping are usually struck on the head when caught, which, it is said, protracts the term of this capability; and the muscles which retain this property longest are those about the head. Many tranverse sections of the muscles being made, and the fish immersed in cold water, the contractions called crimping take place in about five minutes; but, if the mass be large, it often requires thirty minutes to complete the process.

Two flounders, each weighing 1926 grains, the one being in a state for crimping, the other dead and rigid, were put into water at 48°, each being equally scored with a knife. After half an hour, the crimped fish had gained in weight 53 grains, but the dead fish had lost 7 grains. The specific gravity of the crimped fish was greater than that of the dead fish, but a quantity of air-bubbles adhered to the surfaces of the crimped muscles, which were rubbed off before weighing; this gas was not inflammable.

The specific gravity of the crimped fish - - 1,105
of the dead fish, after an equal
immersion in water - 1,090.

So that the accession of water specifically lighter than the muscle of fish, did not diminish the specific gravity of crimped muscle, but the contrary: a proof that condensation had taken place.

A piece of cod-fish weighing twelve pounds, gained in weight, by crimping, two ounces avoirdupois; and another less vivacious piece, of fifteen pounds, gained one ounce and half.*

The hinder limb of a frog, having the skin stripped off, and weighing $77\frac{1}{10}$ grains, was immersed in water at 54°, and suffered to remain nineteen hours, when it had become rigid, and weighed $100\frac{1}{4}$ grains. The specific gravity of the contracted limb had increased, as in the crimped fish.

Six hundred and thirty grains weight of the subscapularis muscle of a calf, which had been killed two days from the 10th of January, was immersed in New River water at 45°. After ninety minutes, the muscle was contracted, and weighed in air 770 grains: it had also increased in specific gravity, but the quantity of air-bubbles formed in the intersticial spaces of the reticular membrane made it difficult to ascertain the degree.

Some of the smallest fasciculi of muscular fibres from the same veal, which had not been immersed in water, were placed on a glass plate, in the field of a powerful microscope, and a drop of water thrown over them, at the temperature of 54°, the atmosphere in the room being 57°. They instantly began to contract, and became tortuous.

On confining the ends of another fibril with little weights of glass, it contracted two-thirds of its former length, by similar

* I am informed that the crimping of fresh water fishes requires hard water, or such as does not suit the purposes of washing with soap. This fact is substantiated by the practice of the London fishmongers, whose experience has taught them to employ pump water, or what is commonly called hard water.

treatment. The same experiment was made on the muscular fibres of lamb and beef, twelve hours after the animals had been killed, with the like results. Neither vinegar, nor water saturated with muriate of soda, nor strong ardent spirit, nor olive oil, had any such effect upon the muscular fibres.

The amphibia, and coleopterous insects, become torpid at 34°. At 36° they move slowly, and with difficulty; and, at a lower temperature their muscles cease to be irritable. The muscles of warm-blooded animals are similarly affected by cold.

The hinder limbs of a frog were skinned and exposed to cold at 30°, and the muscles were kept frozen for eight hours, but on thawing them, they were perfectly irritable.

The same process was employed in the temperature of 20°, and the muscles kept frozen for twelve hours, but that did not destroy the irritability.

In the heat of 100°, the muscles of cold-blooded animals fall into the contractions of death; and at 110°, all those of warm blood, as far as these experiments have been extended. The muscles of warm-blooded animals, which always contain more red particles in their substance than those of cold blood, are sooner deprived of their irritability, even although their relative temperatures are preserved; and respiration in the former tribe is more essential to life than in the latter.

Many substances accelerate the cessation of irritability in muscles when applied to their naked fibrils, such as all the narcotic vegetable poisons, muriate of soda, and the bile of animals; but they do not produce any other apparent change in muscles, than that of the last contraction. Discharges of electricity passed through muscles, destroy their irritability, but leave them apparently inflated with small bubbles of gas;

perhaps some combination obtains which decomposes the water.

The four separated limbs of a recent frog were skinned, and immersed in different fluids; *viz.* No. 1, in a phial containing six ounces by measure of a saturated aqueous solution of liver of sulphur made with potash; No. 2, in a diluted acetic acid, consisting of one drachm of concentrated acid to six of water; No. 3, in a diluted alkali, composed of caustic vegetable alkali one drachm, of water six ounces; No. 4, in pure distilled water.

The phials were all corked, and the temperature of their contents was 46°.

The limb contained in the phial No. 1, after remaining twenty minutes, had acquired a pale red colour, and the muscles were highly irritable.

The limb in No. 2, after the same duration, had become rigid, white, and swollen; it was not at all irritable. By removing the limb into a diluted solution of vegetable alkali, the muscles were relaxed, but no signs of irritability returned.

No. 3, under all the former circumstances, retained its previous appearances, and was irritable, but less so than No. 1.

No. 4 had become rigid, and the final contraction had taken place.

Other causes of the loss of muscular irritability occur in pathological testimonies, some examples of which may not be ineligible for the present subject. Workmen whose hands are unavoidably exposed to the contact of white lead, are liable to what is called a palsy in the hands and wrists, from a torpidity of the muscles of the fore arm. This affection seems to be decidedly local, because, in many instances, neither the brain, nor the other members, partake of the disorder; and it oftenest affects the right hand. An ingenious practical chemist in London has frequently experienced spasms and rigidity in the muscles of his fore arms, from affusions of nitric acid over the cuticle of the hand and arm. The use of mercury occasionally brings on a similar rigidity in the masseter muscles.

A smaller quantity of blood flows through a muscle during the state of contraction, than during the quiescent state, as is evinced by the pale colour of red muscles when contracted. The retardation of the flow of blood from the veins of the fore arm, during venæsection, when the muscles of the limb are kept rigid, and the increased flow after alternate relaxations, induces the probability, that a temporary retardation of the blood in the muscular fibrils takes place during each contraction, and that its free course obtains again during the relaxation. This state of the vascular system in a contracted muscle, does not, however, explain the diminution of its bulk, although it may have some influence on the limb of a living animal.

When muscles are vigorously contracted, their sensibility to pain is nearly destroyed; this means is employed by jugglers for the purpose of suffering pins to be thrust into the calf of the leg, and other muscular parts with impunity: it is indeed reasonable to expect, *a priori*, that the sensation, and the voluntary influence, cannot pass along the nerves at the same time.

In addition to the influences already enumerated, the human muscles are susceptible of changes from extraordinary occurrences of sensible impressions. Long continued attention to interesting visible objects, or to audible sensations, are known to exhaust the muscular strength: intense thought and anxiety, weaken the muscular powers, and the passions of grief and fear produce the same effect suddenly: whilst the contrary feelings, such as the prospect of immediate enjoyment, or moderate hilarity, give more than ordinary vigour.

It is a very remarkable fact in the history of animal nature, that the mental operations may become almost automatic, and, under such habit, be kept in action, without any interval of rest, far beyond the time which the ordinary state of health permits, as in the examples of certain maniacs, who are enabled without any inconvenience, to exert both mind and body for many days incessantly. The habits of particular modes of labour and exercise are soon acquired, after which, the actions become automatic, demand little attention, cease to be irksome, and are effected with little fatigue: by this happy provision of nature, the habit of industry becomes a source of pleasure, and the same appears to be extended to the docile animals which co-operate with man in his labours.

Three classes of muscles are found in the more complicated animals. Those which are constantly governed by the will, or directing power of the mind, are called voluntary muscles. Another class, which operate without the consciousness of the mind, are denominated involuntary; and a mixed kind occur in the example of respiratory muscles, which are governed by the will to a limited extent; nevertheless the exigencies of the animal feelings eventually urge the respiratory movements in despight of the will. These last muscles appear to have become automatic by the continuance of habit.

The uses of voluntary muscles are attained by experience, imitation, and instruction: but some of them are never called into action among Europeans, as the muscles of the external ears, and generally the occipito-frontalis. The purely involuntary muscles are each acted upon by different substances, which appear to be their peculiar stimuli; and these stimuli co-operate with the sensorial influence in producing their contractions: for example, the bile appears to be the appropriate stimulus of the muscular fibres of the alimentary canal below the stomach, because the absence of it renders those passages torpid. The digested aliment, or perhaps the gastric juice in a certain state, excites the stomach. The blood stimulates the heart, light the iris of the eye, and mechanical pressure seems to excite the muscles of the œsophagus. The last cause may perhaps be illustrated by the instances of compression upon the voluntary muscles, when partially contracted, of which there are many familiar examples. Probably the muscles of the ossicula auditûs are awakened by the tremors of sound; and this may be the occasion of the peculiar arrangement observable in the chorda tympani, which serves those muscles.

These extraneous stimuli seem only to act in conjunction with the sensorial power, derived by those muscles from the gangliated nerves, because the passions of the mind alter the muscular actions of the heart, the alimentary canal, the respiratory muscles, and the iris; so that probably the respective stimuli already enumerated, only act subserviently, by awakening the attention of the sensorial power, (if that expression may be allowed,) and thereby calling forth the nervous influence, which, from the peculiar organization of the great chain of sympathetic nerves, is effected without consciousness: for, when the attention of the mind, or the more interesting passions prevail, all the involuntary muscles act irregularly, and unsteadily, or wholly cease. The movements of the iris of the common parrot is a striking example of the mixed influence.

The muscles of the lower tribes of animals, which are often entirely supplied by nerves coming from ganglions, appear of this class; and thus the animal motions are principally regulated by the external stimuli, of which the occurrence seems to agree with the animal necessities: but the extensive illustrations which comparative anatomy affords on this point, are much too copious for any detail in this place.

There are two states of muscles, one active, which is that of contraction, the other, a state of ordinary tone, or relaxation, which may be considered passive, as far as it relates to the mind; but the sensorial or nervous power seems never to be quiescent, as it respects either the voluntary or involuntary muscles during life. The yielding of the sphincters appears to depend on their being overpowered by antagonist muscles, rather than on voluntary relaxation, as is commonly supposed.

I have now finished this endeavour to exhibit the more recent historical facts connected with muscular motion.

It will be obvious to every one, that much remains to be done, before any adequate theory can be proposed. I have borrowed from the labours of others, without acknowledgement, because it would be tedious to trace every fact, and every opinion to its proper authority: many of the views are perhaps peculiar to myself, and I have adduced many general assumptions and conclusions, without offering the particular evidence for their confirmation, from a desire to keep in view the remembrance of retrospective accounts, and to combine them with intimations for future research. The due cultivation of this interesting pursuit cannot fail to elucidate many of the phenomena in question, to remove premature and ill founded physiological opinions, and eventually to aid in rendering the medical art more beneficial, by establishing its doctrines on more extensive and accurate views of the animal economy.

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