XVI. *Chemical Experiments on Zoophytes; with some Observations on the component Parts of Membrane. By* Charles Hatchett, *Esq. F. R. S.*

Read June 12, 1800.

THE experiments and observations on shell and bone, which I had the honour last year to lay before this learned Society, were made in consequence of my having discovered, some little time before, that the enamel of teeth did not consist principally of carbonate of lime, as was generally believed, but was of a nature similar to bone; with this difference, that the phosphate of lime was not deposited in and upon a cartilaginous or membranaceous substance, but was only blended with a certain portion of animal gluten.* By the experiments subsequently made on various shells, crustaceous substances, and bones, it was proved,

1st. That the porcellaneous shells resemble the enamel of teeth in the mode of formation, but that the hardening substance is carbonate of lime.

2dly. That shells composed of nacre or mother of pearl, or approaching to the nature of that substance, and also pearls,

* See experiments mentioned in Observations on the teeth of graminivorous quadrupeds, &c. by EVERARD HOME, Esq. F. R. S. Phil. Trans. for 1799, p. 243.

resemble bone in a considerable degree, as they consist of a gelatinous, cartilaginous, or membranaceous substance, forming a series of gradations, from a tender and scarcely perceptible jelly to membranes completely organized, in and upon which carbonate of lime is secreted and deposited, after the manner that phosphate of lime is in the bones; and therefore, as the porcellaneous shells resemble the enamel of teeth, so the shells formed of mother of pearl, *&c.* in like manner resemble bone; the distinguishing chemical character of the shells being carbonate of lime, and that of enamel and bones being phosphate of lime.

3dly. It was proved, that the crust which covers certain marine animals, such as crabs, lobsters, crayfish, and prawns, consists of a strong cartilage, hardened by a mixture of carbonate and phosphate of lime; and that thus these crustaceous bodies occupy a middle place between shell and bone, although they incline principally to the nature of shell. And,

4thly. It was proved, that a certain portion of carbonate of lime enters the composition of bones in general; the proportion of it however being, to the phosphate of lime, *vice versâ* to that observed in the crustaceous marine substances.

Upon the view, therefore, of these facts, it is evident, that there is a great similarity in the construction of shell and bone; and that there is even an approximation in the nature of their composition, by the intermediate crustaceous substances.

These remarks, with the experiments by which they are supported, form the principal features of that paper, which the Royal Society honoured with a place in the last volume of the Philosophical Transactions. At that time, it was not my intention immediately to pursue the subject; but I changed this resolution, after a conversation with my friend Dr. GRAY, Sec. R.S. who suggested, that many marine substances still remained to be examined in a similar manner; and that a series of experiments on Zoophytes (hitherto but little known in respect to their component parts) would be very interesting, and might probably lead to some improvement in their classification.

I was therefore induced to make the experiments contained in the following pages; and, as the mode adopted was very similar to that which was formerly pursued, it appears superfluous here to repeat the description.

It will be proper, however, to observe, that argill is not unfrequently lodged, as an extraneous substance, in the interstices of many of the Madrepores, and such like bodies; and, as argill is precipitated by pure ammoniac, it became necessary not to rely merely on the ammoniac, as a test of phosphate of lime.

Whenever, therefore, any precipitate was produced by ammoniac, it was dissolved again in acetous acid, and this solution was examined by the addition of acetite of lead.

§ I. EXPERIMENTS ON ZOOPHYTES.

*Madrepora virginea.**

This Madrepore, when immersed in very dilute nitric acid, effervesced much, and was soon dissolved.

The solution was perfectly transparent and colourless, with

* The different species are named according to GMELIN's edition of LINNÆUS's *Systema Naturæ.*

but a small appearance of gelatinous or membranaceous particles. Pure ammoniac was then added, but did not cause any alteration; and the whole of what had been dissolved, was afterwards completely precipitated by carbonate of ammoniac, and proved to be carbonate of lime.

Madrepora muricata.

When treated like the former, it afforded some loose particles of a gelatinous substance: these were separated by a filter, and the solution was supersaturated with pure ammoniac, without effect; but, upon adding carbonate of ammoniac, the dissolved part was precipitated, in the state of carbonate of lime.

Madrepora labyrinthica.

This, being examined in the manner abovementioned, proved to be composed of carbonate of lime, and of a loose gelatinous substance, similar to that afforded by *Madrepora muricata.*

Madrepora ramea.

When this Madrepore was first immersed in very dilute nitric acid, a considerable effervescence was produced; and, after a few hours, a pale brown fibrous membrane remained, which in some measure exhibited the original figure of the Madrepore. The clear solution being poured into another vessel, only afforded a large quantity of carbonate of lime.

Madrepora fascicularis.

When this was put into very dilute nitric acid, a considerable effervescence arose; and, after some hours, a tender membrane was left, which retained the original shape. Pure ammoniac did not disturb the transparency of this solution; but a copious precipitate of carbonate of lime was obtained, by the addition of carbonate of ammoniac.

These experiments, on only a few of the Madrepores, sufficiently prove how similar they are, in composition, to shell; for both consist of the same materials, subject to the like modifications.

Millepora cærulea.

This produced much effervescence, when immersed in very dilute nitric acid. The blue colour disappeared, as the calcareous part was dissolved, and was not afterwards restored by ammoniac.

Some loose detached portions of a gelatinous substance floated in the solution, which were separated by a filter. The transparency of the solution was not disturbed by pure ammoniac; but a copious precipitate of carbonate of lime was produced by carbonate of potash.

Millepora alcicornis.

This Millepore, when treated with very dilute nitric acid, produced a great effervescence; and, after a few hours, a tender gelatinous substance remained, which did not retain the figure of the Millepore.

Pure ammoniac had not any effect; but carbonate of ammoniac precipitated a large quantity of carbonate of lime.

Millepora polymorpha.

This produced an effervescence, when put into dilute nitric acid; and, after some hours, a substance remained, which completely retained the original figure of the Millepore.

The substance which thus remained, was composed of a strong white opaque membrane, which formed the external part; the interior of this, was filled with a transparent gelatinous substance. Ammoniac produced a very slight precipitate, which, being dissolved in acetous acid, was proved to be phosphate of lime, by solution of acetite of lead. Carbonate of soda afterwards precipitated a large quantity of carbonate of lime.

Millepora cellulosa.

This Millepore effervesced much with dilute nitric acid; and, when this had ceased, a finely perforated membrane remained, in structure and appearance like the original substance.

Ammoniac did not produce any effect; but a large quantity of carbonate of lime was obtained by carbonate of soda.

Millepora fascialis.

This resembled the former in every particular; and left a membrane perfectly like the Millepore.

Millepora truncata.

When treated with dilute nitric acid, it effervesced much, like the former; and, after a few hours, a semi-transparent membranaceous substance remained, which exhibited completely the shape and structure of the original Millepore.

Ammoniac did not disturb the transparency of the solution; but the whole of the dissolved portion was precipitated, in the state of carbonate of lime, by carbonate of ammoniac.

The remark lately made on the Madrepores may here also be repeated, as the composition of the Millepores appears to be the same, with the single exception of *Millepora polymorpha*, which afforded some slight traces of phosphate of lime. But time and future experiments will shew whether this was an accidental circumstance, or whether the *Millepora polymorpha* is thus distinctly characterised.

It is likewise necessary to add, that when these various Madrepores and Millepores were exposed to red heat, in a crucible, they emitted smoke, with the smell of burned horn or feathers, became tinged with a paler or deeper gray colour, and (when dissolved in acids) deposited more or less animal coal, in proportion to the quantity of the gelatinous or membranaceous substance detected by the experiments lately described.*

Tubipora musica

Of the *Tubiporæ*, I had only an opportunity to examine this species.

Like the former substances, it was immersed in an acid, and on this occasion I employed the acetous acid. A great effervescence was produced, and the red colour was destroyed, in proportion as the calcareous part was dissolved. When the solution was completely effected, some loose particles of a tender membrane floated in the liquor, and were separated by a filter.

Pure ammoniac, added to the solution, produced a precipitate; which proved to be argill, accidentally lodged in the interstices of the Tubipore.

* The order in which these experiments are placed, is not that according to which they were made; but it has been adopted, because it shews more evidently the gradations of the membranaceous substances.

To the filtrated liquor, carbonate of potash was added, and precipitated a large quantity of carbonate of lime.

Flustra foliacea.

When this was immersed in very dilute nitric acid, an effervescence of short duration took place; and, when this had ceased, the *Flustra* appeared like a finely reticulated membrane, which retained the original shape.

Pure ammoniac being added to the filtrated solution, produced a slight precipitate; which, being dissolved in acetous acid, was proved, by acetite of lead, to be phosphate of lime.

Solution of carbonate of ammoniac was then added to the liquor from which the phosphate of lime had been separated, and produced a copious precipitate of carbonate of lime.

When the *Flustra foliacea* was exposed to a low red heat, in a crucible, it emitted a smell like burned horn, but retained its shape, by reason of the carbonate of lime with which it was coated. The *Flustra* thus burned, when dissolved in dilute nitric acid, deposited some animal coal; but, in other respects, the present solution resembled the former nitric solution of this substance when in a recent state.

The *Flustra foliacea,* when long digested with boiling distilled water, communicated to it a pale brownish tinge. Infusion of oak bark being then poured into the liquor, did not produce any visible effect, even after 24 hours had elapsed; but nitro-muriate of tin formed a white cloud, in the space of a few minutes.

Corallina Opuntia.

This being put into very dilute nitric acid, produced (like the *Flustra foliacea*) an effervescence of short duration.

The coralline then remained in a membranaceous state, and retained the original figure. To the filtrated solution some pure ammoniac was added, but it scarcely produced any visible effect.

Carbonate of ammoniac precipitated a large quantity of carbonate of lime.

Some of the *Corallina Opuntia* was then exposed to a low red heat, in a crucible; it emitted a smell of burned horn, and in great measure retained its shape, evidently from the calcareous coating.

The burned coralline, being dissolved in dilute nitric acid, deposited some animal coal.

The clear solution afforded, by pure ammoniac, a very slight precipitate of phosphate of lime; after which, the carbonate of lime was precipitated as before.

This coralline, when treated with boiling water, like the *Flustra foliacea*, did not discolour it; neither was the water changed by infusion of oak bark; but nitro-muriate of tin produced a faint white cloud.

Isis ochracea.

When this *Isis* was immersed in dilute nitric acid, a considerable effervescence was produced; and, in proportion as the calcareous substance was dissolved, the red colouring matter was deposited, in the state of a fine red powder.*

When the effervescence had ceased, (which was after about three hours,) a yellowish membrane remained, which completely retained the original figure of the *Isis*.

* This colouring substance was not dissolved, nor changed, when nitric or muriatic acids were poured upon it. It appears, therefore, to be very different from the tinging matter of the *Tubipora musica*, or that of the *Gorgonia nobilis*.

The solution, being filtrated, was saturated with pure ammoniac, by which, a slight precipitate of phosphate of lime was separated. A large quantity of carbonate of lime was afterwards precipitated, by solution of carbonate of potash.

Part of a branch of this *Isis* was put into a crucible heated to a low red heat. A great quantity of smoke was emitted, which had the smell of burned horn; and, after a few minutes, the branch separated at the knotty joints, into as many pieces as there were joints in the branch. These joints had all the characters of coral; but the whole of the membrane which had invested them, as well as the knotted protuberances by which they had been connected, were destroyed, by being converted into coal. From this circumstance, I was desirous to examine the internal structure of the membranaceous part, out of which these joints of coral had been dissolved by acids.

I took, therefore, the membranaceous substance which remained after the first experiment, and which (as I have already observed) retained the complete figure of the *Isis.*

This substance being opened longitudinally, exhibited a series of cavities, corresponding in form with the coralline joints, and so situated, that each of these cavities extended from one bulb or knot nearly to the next, throughout the whole of the branch.

The coralline joints, when viewed separately, appeared smaller in the middle than at the ends, which were terminated by obtuse cones.

In the branch, these joints were so placed, that the extremities or cones were opposed point to point; but were prevented from immediate contact, by a gristly substance, which filled, and indeed principally formed in the branch, the knot or bulb of each joint, and was interposed between the cones of the coralline substance, like the common cartilages of the articulations.

From this construction it appears, that this *Isis* is capable of great flexibility when in a recent state; for the gristly part of the bulbs is then most probably much softer, and more elastic, than it appears to be in the dried specimens which are found in collections.*

The gristly substance which forms the bulbs, and the coralline joints, are kept together, and are covered, by a thin skin or membrane, which is continued over the whole, like a tube. The joints are not, therefore, devoid of a coating, as seems to be implied by the definition of LINNÆUS.

Isis Hippuris.

Part of a branch of this *Isis* was immersed in very dilute nitric acid, and a considerable effervescence immediately took place. When this effervescence had ceased, there appeared little or no change in the original form of the *Isis;* but the coralline joints were now become a soft, compact, white, and opaque membranaceous substance; while the dark brown intermediate parts retained also their form, and in other characters resembled those of horn.

The solution was colourless and transparent. When saturated with pure ammoniac, it was not affected; but carbonate of potash produced a copious precipitate of carbonate of lime.

Another part of this *Isis* was exposed to a low red heat, in a

* It must here be observed, that the articulated structure abovementioned, is not to be found in those parts which form the main stem, with its larger branches; the joints in those parts being consolidated, so as to constitute a strong and rigid trunk, upon which the whole fabric is supported.

crucible. The dark brown horny parts swelled, and puffed up, with much smoke, and a smell like that of burned horn.

The coralline joints also emitted the same smoke and smell, and became dark gray.

When put into dilute nitric acid, a solution was made, with effervescence, during which, there was a copious deposition of animal coal.

From this solution, nothing but carbonate of lime was obtained by the usual precipitants.

A tube of membrane invests the curious structure of the *Isis ochracea;* but no such tube or outer coat exists in the *Isis Hippuris;* for the coralline joints (like some of the Madrepores, Millepores, *&c.)* consist of a membranaceous substance, hardened by carbonate of lime, and the only difference appears to be, that in the Madrepores and Millepores, the membranaceous part is less compact and abundant; but, even the striæ of the coralline joints remain visible, and unchanged, in the membrane of this *Isis.*

The brown horny part forms also a marked characteristic in this *Isis*, and seems to approach it to certain of the *Gorgoniæ.*

This horny part does not however pervade the whole of the branch; for, where the coralline joints commence, this horny substance immediately terminates, internally as well as externally, and is not to be discovered but between or in the separation of these joints.

Gorgonia nobilis.

I next proceeded to examine the *Gorgonia nobilis* or red coral; and, of this, I separately subjected to experiment different pieces, some of which were polished, and deprived of their external, pale red, mealy coat, whilst others were in their original state.

A piece of the unpolished red coral being put into dilute nitric acid, an effervescence immediately took place; and, after some hours, the whole of the calcareous substance was completely dissolved.

The external coat retained the original figure, and appeared like a pale yellow tubulated membrane, the interior of which was filled with a transparent gelatinous substance. From the solution I only obtained a large quantity of carbonate of lime.

The next experiment was made in a manner exactly similar to the former; but a piece of the polished or uncoated red coral was now taken.

The effects produced by the diluted acid were the same as before; but, in the solution, some loose portions of a transparent yellow gelatinous substance were now only to be seen.

The filtrated solution was treated as in the former experiment, and afforded a considerable quantity of carbonate of lime.

As it was possible that the action of the nitric acid (although much diluted) might be too powerful, I was induced to try the effects of acetous acid, in which I immersed a piece of the red coral in its natural state. It was gradually dissolved, with a slow effervescence, and left an external tubulated membrane, retaining the original form, and filled with a transparent gelatinous substance, as in the first experiment.

The solution, when filtrated, afforded carbonate of lime.

A piece of the polished or uncoated red coral was treated with acetous acid, in a similar manner.

It was slowly dissolved, and left a transparent gelatinous substance, like that which has already been mentioned, excepting that it was not in detached portions.

This solution, like the former, only yielded carbonate of lime.

It may here be observed, that in each of the above related experiments, the red colour of the coral was gradually destroyed, as the solution of the calcareous substance advanced, and could not afterwards by any means be restored; nor could any colouring principle whatever be detected by the re-agents usually employed.

A piece of red coral, in its natural or uncoated state, was exposed to a low red heat, in a crucible, during about ten minutes, at which time a faint smell of burned horn was to be perceived. When the coral was taken out of the crucible, it had completely lost the red colour, and was become pale gray. It dissolved in dilute nitric acid, with effervescence, and some animal coal was separated.

To the filtrated solution pure ammoniac was added, and produced a very slight precipitate, which was collected, and was afterwards dissolved in acetous acid. From this solution, by the addition of acetite of lead, some phosphate of lead was obtained.

The carbonate of lime was afterwards precipitated in the usual manner.

As the very small portion of phosphate of lime discovered in the preceding experiment, (and which had escaped the action of the acids then employed,) might be only contained in the coating or epidermis, a piece of the polished or uncoated coral was treated in a similar manner; but, upon examining the solution, it afforded a small portion of phosphate, with a large quantity of carbonate of lime; so that the result of this experiment did not differ from that of the former.

From the preceding experiments it appears, that the *Gorgonia nobilis* or red coral, consists of two parts; one of which is the stem, formed of a gelatinous substance, hardened by carbonate of lime, and coloured by some unknown modification of animal matter; the other is a membranaceous tube, which, like a cuticle or cortex, coats the stem abovementioned, and (when deprived of its hardening substance) possesses all the characters of membrane. But, although carbonate of lime could only be discovered, when this *Gorgonia* was simply immersed in acids, yet it has been proved by these experiments, that a small portion of phosphate of lime is also present, but so enveloped by the membranaceous and gelatinous parts, as not to be dissolved by the acid menstrua, till these substances have been decomposed by fire.

This is not an unusual circumstance, when a very small portion of a substance is enveloped by large quantities of other matter; for, BERGMANN, in his supplement to SCHEELE's Essay on the *Calculus Vesicæ*, observes, that the presence of calcareous earth in certain calculi, could not be discovered in the usual manner, but by operations made expressly for the purpose.*

I do not pretend to determine whether the very small portion of phosphate of lime in the *Gorgonia nobilis* is an essential ingredient or not; but the mode of construction evidently proves how much this *Gorgonia* differs from the Madrepores and Millepores, as well as from the *Gorgoniæ* about to be mentioned.

* SCHEELE's Essays, translated by Dr. BEDDOES. Page 208.

Gorgonia ceratophyta.

When this was immersed in dilute nitric acid, an effervescence was produced; after which, the cortical part appeared like a thin yellowish membrane investing the stem, which was become transparent, and similar to cartilage.

Ammoniac precipitated from the solution a large quantity of phosphate of lime; and lixivium of potash separated some carbonate of lime.

A quantity of the cortex (which had been separated from the stem by beating it between folded writing paper) was steeped in the dilute acid. This solution afterwards, with ammoniac, scarcely afforded a vestige of phosphate of lime; but, when lixivium of carbonate of potash was added, a considerable quantity of carbonate of lime was obtained.

The stem, on the contrary, when thus treated, afforded much phosphate of lime, and very little of the carbonate. When burned in a crucible, it smoked, and emitted a smell like burned horn, but the figure was not destroyed; and, when afterwards dissolved in the acid, it yielded the same products as before.

Gorgonia Flabellum.

When this *Gorgonia* was steeped in dilute nitric acid, it produced an effervescence of short duration. The cortical part then appeared like a thin yellowish membrane, which covered the stem.

The latter was transparent, and resembled softened horn of a reddish brown colour.

The solution afforded a large quantity of phosphate of lime, by the addition of ammoniac; after which, lixivium of potash formed a less copious precipitate of carbonate of lime.

Some parts of the cortex were separated, by beating the *Gorgonia* between folded writing paper, and were immersed in the acid.

This solution was scarcely rendered turbid by ammoniac; but afforded a considerable portion of carbonate of lime by potash.

The stem from which the above cortical part had been separated, was next examined by the dilute acid, in which, when steeped during three days, it became soft, elastic, and in some measure cartilaginous.

The acid was saturated with pure ammoniac, and then changed to a deep yellow or orange colour: a large quantity of phosphate of lime was at the same time separated; and but very little carbonate of lime was afterwards precipitated by potash.

The recent stem in great measure retained its shape, when put into a red-hot crucible; but that which had been steeped in the acid, curled up, and soon became a shapeless mass of coal, which, by a longer continuation of the red heat, was completely dissipated.

This difference appears to have been caused by the phosphate of lime, which was present in the recent stem, but was dissolved and separated in the latter case by the acid.*

These experiments prove, that the *Gorgonia Flabellum*, like the *Gorgonia ceratophyta*, consists of a horny stem, containing a certain portion of phosphate of lime; and that this stem is invested with a membrane, hardened principally by carbonate of

* These different effects are to be observed, when bone, and when the cartilage or membrane which remains after bone has been long steeped in acids, are subjected to a red heat.

lime, which serves to cover and defend it, in the manner of a shell.*

Gorgonia suberosa.

The cortical part of this *Gorgonia* was separated from the stem, and was first subjected to experiment.

Some portions of this cortex were immersed in dilute nitric acid; and, after an effervescence which continued several hours, a soft yellowish membranaceous substance remained, retaining the original figure.

The liquor, when decanted, was pale yellow, which colour was much deepened by the addition of ammoniac; at the same time, a small quantity of phosphate of lime was deposited.

A considerable portion of carbonate of lime was afterwards precipitated by carbonate of potash.

Some pieces of the cortex were boiled with distilled water during about six hours; and, to the filtrated liquor, infusion of oak bark was added, by which, a large quantity of gelatin was precipitated.

The same pieces were afterwards boiled with lixivium of caustic potash, which effected a perfect solution, and formed the animal soap of CHAPTAL; at the same time, the calcareous matter subsided to the bottom of the matrass.

The cortical part of this *Gorgonia*, when put into a red-hot crucible, emitted much smoke, with a smell like horn that is

* It may here be proper to observe, that the membranaceous part of all these substances, such as the Madrepores, Millepores, *Flustra*, &c. &c. was dissolved, when these bodies were boiled with lixivium of caustic potash; and animal soap was formed. The same may also be said of shells; and Mr. VAN MONS has noticed this effect on those of the oyster. See *Annales de Chimie*, Tome XXXI. p. 123.

burned; after this, it fell into pieces, which, being dissolved in nitric acid, afforded a small portion of phosphate of lime, and a large quantity of carbonate of lime.

When the stem of this *Gorgonia* was steeped during 14 or 15 days in dilute nitric acid, it tinged it with pale yellow. The stem, after this, appeared more transparent and flexible, so as to approach the characters of cartilage.

The yellow liquor was changed to a deep yellow or orange colour by the addition of ammoniac; but did not yield any precipitate, even when carbonate of potash was added.

Part of a stem was cut into small pieces, and was boiled for several hours with distilled water.

When filtrated, the water had acquired a very pale yellow tinge; and, upon the addition of infusion of oak bark, yielded a slight precipitate of gelatin.

Lixivium of caustic potash was then poured upon the same pieces; and, being boiled, a thick dark-coloured viscid substance was formed, which possessed all the characters of CHAPTAL'S animal soap.

When the stem of this *Gorgonia* was exposed to a red heat in a retort, or crucible, it curled up, and smelled like burned horn; after which, a spongy coal remained, of difficult incineration.

By a long continuation of the heat, a residuum was left, so small as scarcely to be collected, which, being dissolved in dilute nitric acid, afforded, by the addition of ammoniac, a slight precipitate of phosphate of lime.

Another species of *Gorgonia*, which much resembled the *suberosa*, (excepting that the cortical part was much larger in proportion to the stem,) was next subjected to examination, and proved to be of a similar composition with those already mentioned.

Gorgonia pectinata.

The cortical part of this *Gorgonia* effervesced with dilute nitric acid, and left a soft yellowish white membrane.

Ammoniac precipitated a small quantity of phosphate of lime; after which, a copious precipitate of carbonate of lime was obtained by potash.

The stem, in its habits, resembled those which have been described.

Gorgonia setosa.

An effervescence was produced upon the immersion of this *Gorgonia* in dilute nitric acid; and, after some hours, the cortical part appeared like a thin yellowish membrane, which coated the horny stem.

The acid solution, upon the addition of ammoniac, yielded a slight precipitate of phosphate of lime; and a large quantity of carbonate of lime was afterwards obtained by potash.

When the cortex was separately steeped in the acid, and the solution examined in the way so often mentioned, only carbonate of lime was obtained.*

On the contrary, the stem (whether recent or burned) afforded a small portion of phosphate of lime, but scarcely any trace of carbonate. The stem which had been long steeped in the acid, became soft and transparent, like a cartilaginous or tendinous substance.

* When the cortical part had been long digested in boiling distilled water, a brownish solution was formed, which was but little affected by infusion of oak bark; but nitro-muriate of tin produced a precipitate.

The *Gorgoniæ* which have been enumerated, much resemble each other in the composition of their cortices, as well as in the nature of their stems.

In the cortex, the predominant hardening substance is carbonate of lime; but, in the stem, phosphate of lime is the chief and almost the only earthy substance that is present.

The following *Gorgoniæ* (although in like manner invested by a cortex) are different, as they do not afford any phosphate of lime.

Gorgonia Umbraculum,
Gorgonia verrucosa,

and three other species not described, so much resemble each other in their chemical characters, that it would be superfluous to give a separate account of them.

The cortical parts of these *Gorgoniæ* were separately immersed in dilute nitric acid. An effervescence immediately took place, and, after some time, they were found in the state of soft, pulpy, yellowish white membranaceous bodies, retaining nearly their original size and form.

The acid solutions did not afford any phosphate of lime when ammoniac was added; but a large portion of carbonate of lime was precipitated by solution of potash.

The stems of these *Gorgoniæ*, when immersed during 14 days or more in the dilute acid, were very little affected, excepting, that they became softer and transparent, so as to approach the characters of cartilage or softened horn.*

* The stems of the various *Gorgoniæ*, which had been thus softened by long immersion in dilute nitric acid, became of a deep reddish orange colour, inclining to

The acid in which they had separately been steeped, did not afford any precipitate by the addition of the alkalies; and the only change was in the colour, which became deep yellow when ammoniac was added.

The *Gorgoniæ* now to be mentioned, differ from the former, as they are not coated with a fleshy or pulpy cortical substance. They are here placed immediately before the *Antipathes*, on account of their great similarity in chemical properties, as well as in external appearance.

Gorgonia Antipathes.

Some pieces of this *Gorgonia* were immersed in dilute nitric acid during three weeks, at the end of which time they were much softened, and appeared to be composed of a pale brown, opaque, membranaceous substance, which formed concentrical coats, of a ligneous aspect.

The acid in which these pieces had been steeped, was become pale yellow, and changed to orange colour when ammoniac was added; but not the smallest precipitate could be thus obtained; nor was any alteration caused by the addition of lixivium of potash.

When distilled water was boiled with the *Gorgonia Antipathes* during about six hours, it became slightly tinged with yellow; and, some infusion of oak bark being added, a small quantity of gelatin was precipitated.

The pieces of this substance which had been thus treated, were afterwards boiled with lixivium of caustic potash, by which

brown, when subsequently steeped in pure ammoniac; and, in the course of a few hours, they were completely dissolved.

the whole was dissolved, and a very dark coloured animal soap was formed.

When this *Gorgonia* was exposed to a red heat, it emitted much smoke, with a smell of burned horn: it soon lost its shape, puffed up, and formed a spongy coal, which, by a long continued heat, left a few particles of a white substance, consisting chiefly of muriate of soda.

Another species of *Gorgonia* was next examined, the stem of which is from one quarter to nearly half of an inch in diameter in the thickest parts; of a black colour, and a high polish, like black sealing wax: it has probably been considered as a variety of *Gorgonia Antipathes.*

This, by immersion during 28 days in dilute nitric acid, gradually became semi-transparent, and of a bright brownish yellow. In this softened state, it was steeped two days in water, and was then opened longitudinally. By this, the whole structure became apparent, and consisted of thin coats or tubes of a beautiful transparent membrane, which, beginning from a central point, progressively became larger, according to the order by which they receded from the centre.

These membranes were so delicate, that the fibrous texture could scarcely be discerned.

The acid in which this species had been steeped, was tinged with very pale yellow. Ammoniac being added, changed it to a deep yellow or orange colour; but the transparency of the liquor was not disturbed by this, or any of the other precipitants which had been employed in the former experiments.

When this *Gorgonia* was exposed to a red heat, it crackled, and emitted a thick smoke, with the smell of burned horn. The shape was soon destroyed, and a compact coal remained.

By continuing the red heat, a very small portion of white matter was obtained, which, as far as the quantity would allow, was proved to be muriate of soda, with some carbonate of the same.

The last species of *Gorgonia* which I shall here mention, is one which so much resembles the *Gorgonia Antipathes* as not easily to be distinguished from it, and, like the preceding, has probably been confounded with it; but, upon closely comparing them, the *Gorgonia* now treated of is found to be more flat in the stem, on the thin sides or edges of which, a number of short spines or protuberances are placed very near each other. That it is very different from the *Gorgonia Antipathes*, will be proved by the subsequent experiments.

Some pieces of this *Gorgonia* were exposed to the action of dilute nitric acid for nearly four weeks.

The structure then became very apparent, and consisted of strong fibres, which were placed nearly in a parallel direction, from one extremity of the branch to the other, and, being closely arranged side by side, formed concentric coats of a pale brown opaque substance; but these coats were by no means so distinct as those observed in the *Gorgoniæ* formerly mentioned, although, like them, the fibrous substance possessed the characters of membrane.

The dilute acid in which these pieces had been steeped, was become pale yellow, which changed to orange colour when ammoniac was added; at the same time, so large a quantity of phosphate of lime was precipitated, that the liquor became thick and viscid.

The phosphate was separated by a filter; and lixivium of potash was added to the clear liquor, without producing any effect.

This *Gorgonia* was digested in boiling distilled water during 18 hours, and tinged it with pale yellow.

Infusion of oak bark was then poured into the liquor, and precipitated a small portion of gelatin.

The pieces employed in the above experiment were next boiled with lixivium of caustic potash, and formed a dark-coloured animal soap; at the same time, the phosphate of lime was separated, and was gradually deposited at the bottom of the matrass.

Part of a large branch of this *Gorgonia* was exposed to a low red heat.

It immediately emitted a thick smoke, with the smell of burned horn; and, after a long continued heat, the phosphate of lime was left, so as to retain the original figure, like bone which has been burned; but, in the present instance, the particles of the mass cohered but feebly.

When this residuum was dissolved, and the phosphate separated in the usual manner, a slight cloud of carbonate of lime was produced by potash.

Antipathes Ulex.

When this had been immersed 14 days in dilute nitric acid, it became transparent, and so much softened, that from a horny substance it now nearly resembled cartilage. The acid in which it had been steeped, changed to a very deep yellow or orange colour when ammoniac was added; but no precipitate could be obtained by this, or by potash.

A portion of this *Antipathes* was digested with boiling distilled water, from which some gelatin was precipitated afterwards by infusion of oak bark.

The *Antipathes* being then boiled with lixivium of caustic potash, was completely dissolved, and formed the animal soap of Mr. CHAPTAL.

Antipathes myriophylla.

This was subjected to experiments like those above related, and, as the effects were the same, it is not necessary that particular mention should here be made of them.

As the specimens of these *Antipathes* were small, I was not able to make any additional experiments; but what has been said sufficiently proves how much they resemble the horny stems of the *Gorgoniæ.*

Sponges.

Many species of Sponge were examined, but, as little or no essential difference was found in the results, I shall include all of them in what is now to be related.

The following species, with many others not described, were subjected to experiment.

Spongia cancellata.
Spongia oculata.
Spongia infundibuliformis.
Spongia palmata.
Spongia officinalis.

When the Sponges had been immersed in nitric acid (diluted with three measures of distilled water) during 14 or 16 days, the acid became pale yellow, and was changed to an orange colour by the addition of pure ammoniac.

The Sponges which had been thus steeped in the dilute acid, became (like the *Gorgoniæ*) more or less transparent, and were considerably softened. In this state, if they were touched with ammoniac, the part thus touched became of a deep orange colour, inclining to a brownish red; and, when much softened by the acid, (if afterwards immersed in ammoniac,) they were completely dissolved, and formed a deep orange-coloured solution.*

When digested with boiling distilled water, the Sponges afforded a portion of animal jelly or gelatin, which was precipitated by infusion of oak bark.

The fine and more flexible Sponges yielded gelatin in greater abundance, and more easily, than those which were coarse and rigid. The gelatin was gradually and progressively imparted to the water, and seems (even in the same Sponge) to be a constituent principle, of different degrees of solubility; and it must be noticed, that in proportion as the Sponges (particularly those which were soft and flexible) were deprived of this substance, in the like proportion they became less flexible and more rigid, so that the remaining part, when dry, crumbled between the fingers; or, when moist, was torn easily, like wetted paper.

As the above properties prove that Sponges only differ from the horny stems of the *Gorgoniæ*, and from the *Antipathes*, by being of a finer and more closely woven texture,† so this similarity will be corroborated by the following remarks.

When exposed to heat, they yielded the same products, the

* The same effects were observed when the horny stems of the *Gorgoniæ, Antipathes, &c.* (which had been long steeped in dilute nitric acid,) were immersed in pure or caustic ammoniac.

† This is particularly to be observed by comparing the coarse sponges (such as *Spongia cancellata*) with the finely reticulated parts of certain *Gorgoniæ*, especially those of *Gorgonia Flabellum*, when divested of the external membrane.

same smell, and afforded a similar coal, which by incineration left a very small residuum, consisting chiefly of muriate of soda, occasionally mixed with some carbonate of lime, which was also often discovered when the recent Sponges were immersed in acids; but this, as well as the muriate of soda, is I believe merely extraneous, and arises from small shells, parts of Madrepores, and such like bodies, which are often visibly lodged in the interstices of the Sponges.

Lastly, the Sponges, when boiled with lixivium of caustic potash, were completely dissolved, and, like the horny stems of the *Gorgoniæ,* formed animal soap, more especially when the part which is apparently insoluble in water, and which remains after the gelatin has been separated, was thus treated.

Alcyonium asbestinum.

This, after being immersed during several hours in dilute nitric acid, remained unchanged in figure; a feeble effervescence was at first produced, and the reddish purple colour was destroyed.

The external part became pale yellow, and was a soft opaque pulpy substance, within which was a stem, very similar in texture, but less soft, and which still appeared of a pale red colour.

When pure ammoniac was added to the filtrated solution, no apparent effect was produced; but carbonate of potash precipitated a large quantity of carbonate of lime.

When a piece of this *Alcyonium* was exposed to a low red heat, it soon took fire, and emitted a smell like burned horn; after which, it retained its figure, and became white. Being dissolved in dilute nitric acid, some animal coal was deposited;

and, upon the addition of ammoniac, a small portion of phosphate of lime was obtained, which being separated, the carbonate was precipitated as before.

Some pieces of this *Alcyonium* were digested with boiling distilled water during six hours; the liquor was then decanted, and infusion of oak bark being added, a quantity of gelatin was precipitated.

On the pieces of the *Alcyonium* from which the water had been decanted, some lixivium of caustic potash was poured; and, being boiled, the whole of the membranaceous or pulpy part was dissolved, and a substance exactly similar to CHAPTAL's animal soap was formed, while the calcareous part subsided to the bottom of the vessel.

Alcyonium Ficus.

When the effervescence produced by pouring dilute nitric acid on this *Alcyonium* had ceased, it was found unchanged in shape, and like a strong thick membranaceous substance of a fibrous texture.

Pure ammoniac, added to the acid liquor, precipitated a small quantity of phosphate of lime; after which, a copious precipitate of carbonate of lime was obtained by potash.

Alcyonium arboreum.

This *Alcyonium*, being steeped in the dilute nitric acid, effervesced, and was acted upon like *Alcyonium asbestinum.*

The calcareous part was soon dissolved; but the form of the *Alcyonium* remained unchanged, and still appeared like a pale yellow porous substance, enveloped by a skin or epidermis.

Ammoniac did not disturb the transparency of the solution; but carbonate of lime was obtained by solution of potash.

When exposed to a low red heat, it resembled *Alcyonium asbestinum;* and a solution being subsequently made, afforded some phosphate of lime, with a large portion of carbonate.

As this phosphate had not been discovered in the first experiment, and therefore appeared to have been defended from the action of the acid by the membranaceous part, that experiment was repeated, with this difference, that the acid was made to boil.

A complete solution of the whole was thus made, which, like that of the burned *Alcyonium,* yielded phosphate of lime; and at the same time the liquor became of an orange colour, as soon as the ammoniac was added.

Some pieces of this *Alcyonium* were digested with boiling distilled water, and tinged it with a pale yellow colour. Infusion of oak bark being then added, a large quantity of gelatin was precipitated.

The same pieces were boiled with lixivium of caustic potash, and, when dissolved, formed animal soap.

The calcareous part was separated during the boiling, and subsided in the form of a fine powder.

From the examination of the few species of *Alcyonium* which have been mentioned, it appears, that as the Sponges resemble the horny stems of *Gorgoniæ,* so these, in external and chemical characters, resemble the fleshy or cortical substance which invests some of those bodies; and that they chiefly differ from the *Gorgoniæ,* by being destitute of the horny stem, which in the latter seems to supply the place of bone.

§ II. OBSERVATIONS ON THE FOREGOING EXPERIMENTS.

The simplicity and uniformity of the experiments here described, will not, I flatter myself, render the facts less worthy of attention; and I must again repeat, that the minutiæ of analysis did not form part of my present plan, which was only to sketch an outline, comprehending the most prominent chemical characteristics of certain bodies appertaining to the animal kingdom, which hitherto had been but little or not at all examined; so that this outline (although defective) might serve as a chain of connection, and as a basis, upon which a more perfect superstructure may in future be gradually raised; and it appeared evident, that this would be most easily and speedily executed, by following a systematical and comparative plan. For this reason, a great part of my attention was directed towards ascertaining, in these animal substances, the presence and general proportions of carbonate and phosphate of lime; these being the materials essentially employed by nature to communicate rigidity and hardness to certain parts of animals, such as shell and bone; and, although some other substances, as magnesia, silex, iron, with some alkaline and neutral salts, might be occasionally present in small proportions, (and indeed were at times detected,) yet, as these appear to have but little influence on the general characters of the bodies which were examined, I did not, for the present, think proper to take particular notice of them.

The next object was, to examine the nature of the substance in and upon which the hardening or ossifying principles were secreted and deposited; and it seemed to me that the best mode to do this, was to compare and examine this substance in the various states in which it appeared, when deprived of the hardening or ossifying matter.

From what was said in the paper on shell and bone, concerning the substance which remained after the carbonate of lime in shells, and after the phosphate of lime in bones, had been dissolved and separated by weak acids, it is evident that the substance which thus remains, is as various in relative quantity, as it is in those qualities which apparently are produced by the degrees of natural inspissation, and by the progressive effects of organization.

In the *porcellaneous shells,* such as *Cypreæ,* &c. this substance was proved to be much less in quantity than in those which were afterwards mentioned; and, although of a quality which (like a cement or gluten) served to bind and connect the particles of carbonate of lime firmly together, so small was the degree of natural inspissation, and so little advanced was the degree of organization, that when the carbonate of lime was dissolved, even by very feeble acids, little or no vestige of jelly, membrane, or cartilage, could be perceived; nor indeed could any be detected, but by the small portion of animal coal which was formed, when these shells had been exposed for a short time to a low red heat.

But, proceeding from shells of this description to others tending to the nature of nacre or mother of pearl, (such as some of the *Patellæ,*) a substance was left *untouched by the acids,* which had the appearance of a yellowish transparent jelly.* So that the substance which served merely as a gluten in the porcellaneous shells, was not only more abundant in these *Patellæ,* but, being more inspissated, was become immediately visible and palpable.

In the common oyster, these qualities were more strongly marked; and, in the river muscle, and in the shells composed

* The term jelly is here employed only to denote the degree of consistency of this substance, which in its nature is very different from the varieties of animal jelly called gelatin.

of the true nacre or mother of pearl, this substance was found not only to constitute a large part of the shell, but even to be more dense, so as no longer to appear gelatinous; and, in addition to these, strong and visible marks of organization were stamped on every part, and a perfect membranaceous body remained, composed of fibres arranged parallel to each other, according to the configuration of the shells.

From these facts, proved by the examination of only a very few (comparatively speaking) of the known shells, it appears that the hardening principle, or carbonate of lime, together with a substance varying from a very attenuated gluten to a tough jelly, and from this to a perfectly organized membrane, concur to form the matter of shell; and, from the result of the experiments, and from all circumstances, there is every reason to believe, that the substance with which, or upon which, the carbonate of lime is mixed or deposited, is of a similar nature, and differs only in relative quantity and density, arising from progressive changes (peculiar to the various species of shells) produced by certain degrees of natural inspissation, and by an organization more or less perfect.

The experiments made on teeth, and on the bones of various animals, elucidated and confirmed the observations made on the nature of shell; for,

1st. The enamel of teeth (in relation to the other bony substances) was proved to be as the porcellaneous shells are to those formed of mother of pearl; the cementing substance of the enamel being a gluten, in the same state, and apparently of a similar nature, with that of the porcellaneous shells. And,

2dly. In certain bones, particularly those of fish, (such as some of the bones of the skate,) the substance which remained after the solution of the phosphate of lime, was of a gelatinous consistency, and exhibited but very imperfect traces of organization; by the others, however, a completely formed membrane or cartilage was left, retaining the figure of the original bone.

When therefore the component parts of shell and bone are considered, it appears that the essential characteristics are, carbonate of lime for the one, and phosphate of lime for the other; and that their bases consist of the modifications of a glutinous, gelatinous, or membranaceous substance.

I experienced much gratification in tracing the progressive and connected changes in the composition of the various shells and bones; and a considerable increase of pleasure arose, in proportion as the observations made on those bodies were corroborated, and the chain of connection extended, by the developement of the facts resulting from the experiments on Zoophytes, which form the principal subject of this paper.

It will now be proper to review these experiments, and to examine how far they agree with those made on shell and bone, and how far they tend to prove, that these substances are all of a nature closely connected.

The experiments on the Madrepores afforded the following results.

Madrepora virginea, when examined by acids, left but very little of any gelatinous substance or membrane.

Madrepora muricata, and *Madrepora labyrinthica*, afforded loose portions of a transparent gelatinous substance.

Madrepora ramea, and *Madrepora fascicularis*, when deprived of the carbonate of lime by acids, remained in the state of completely organized membranaceous bodies, which exhibited the original figure of the respective Madrepores; and the proportion of coal afforded by these last, was more abundant than what was obtained from those which were first mentioned.

To these succeeded the experiments on the Millepores; from which it appeared, that

Millepora cærulea afforded loose detached portions of a gelatinous substance.

Millepora alcicornis yielded the same, but in a more coherent state.

Millepora polymorpha remained unchanged in shape, and consisted of a strong, white, opaque membrane, filled with a transparent jelly.

Lastly, *Millepora cellulosa*, *Millepora fascialis*, and *Millepora truncata*, afforded membranaceous bodies, in a complete state of organization; and all these Millepores, when exposed to a low red heat, yielded various quantities of coal, according to the greater or less abundance of the gelatinous or membranaceous substance.

The universal and only hardening principle of these Madrepores and Millepores, was proved to be carbonate of lime, with the single exception of *Millepora polymorpha*, which also appears to be differently constructed from the other *Milleporæ*. With this single exception, carbonate of lime seems to be the only hardening substance in these bodies; and, when every circumstance is considered, an exact similarity is to be found between the substance forming the various shells, and that which forms the *Madreporæ* and *Milleporæ*; and the nature of these bodies is so completely the same, that the changes or gradations of the one are to be found in the other. For the chemical characters which distinguish the porcellaneous shells, are in a great measure approached by those of *Madrepora virginea*; and those which were noticed in the *Patellæ,* correspond precisely with the Madrepores and Millepores which afford a gelatinous substance; and lastly, the characters of the membranaceous part, exhibited by the shells formed of nacre or mother of pearl, are in like manner to be found among some of the Madrepores and Millepores, such as *Madrepora ramea, Millepora fascialis, Millepora truncata;* for these, like the *Turbo olearius* and *Haliotis Iris,* are composed of a fibrous membrane, hardened by carbonate of lime.

It appears therefore, that the Madrepores and Millepores, like the various shells, are formed of a gelatinous or membranaceous substance, hardened by carbonate of lime; and the only difference is in the mode according to which these materials have been employed.

The experiments on *Tubipora musica* proved, that in composition it resembled the foregoing substances. But a slight difference was observed, in respect to the hardening substance of *Flustra foliacea* and *Corallina Opuntia;* for a small portion of phosphate was found mixed with the carbonate of lime; but the membranaceous part of these bodies resembled that of certain Madrepores and Millepores, particularly *Millepora fascialis.*

Two species of *Isis* were next examined, namely, *Isis ochracea* and *Isis Hippuris:* both of these were proved to be formed of regularly organised membranaceous, cartilaginous, and horny substances, hardened, in the last mentioned species, merely by carbonate of lime; but, in the *Isis ochracea,* with the addition of a very small portion of phosphate of lime.

The subsequent experiments were made on various species of *Gorgonia,* and first on *Gorgonia nobilis,* which was formerly regarded as an *Isis.*

The hardening substance of this was found to be carbonate of lime, with a small portion of phosphate; but the matter forming the membranaceous part was (like that of *Millepora polymorpha*) in two states; that of the interior being gelatinous; and that of the external part being a membrane completely formed, so as to cover the stem, in the manner of a tube.

The results of the experiments on certain *Gorgoniæ*, such as *ceratophyta*, *Flabellum*, *suberosa*, *pectinata*, and *setosa*, were not a little remarkable; for, when the two parts which compose these *Gorgoniæ* (namely, the horny stem, and the cortical substance by which it is coated,) were separately examined, it was proved,

1st. That the stems of these *Gorgoniæ* consist of a substance analogous to horn; and that, by long maceration in diluted nitric acid, this horny substance becomes soft and transparent, so as to resemble a cartilaginous or tendinous body; moreover, the stems of these *Gorgoniæ* afford a quantity of phosphate of lime, but scarcely any trace of carbonate.

2dly. That the cortical part, on the contrary, consists principally of carbonate of lime, with very little or none of the phosphate; and the carbonate of lime is deposited in and upon a soft, flexible, membranaceous substance, which seems much to approach the nature of cuticle.

Some other *Gorgoniæ*, which were subsequently examined, and which much resembled the former in construction, did not yield any phosphate of lime; but in every other particular they proved to be similar.

The *Gorgonia Antipathes* was found to be entirely formed of a fibrous membrane; and the black shining polished *Gorgonia* afforded, by maceration, a most beautiful specimen of membranes concentrically arranged.

Lastly, the *Gorgonia* which I have described as very much resembling the *Gorgonia Antipathes*, proved to be similar to that species, as to the membranaceous part; but so large a portion of phosphate of lime was mixed with it, as almost to approach it to the nature of stag's or buck's horn; there is, therefore, great reason to consider it as a different species.

The *Antipathes*, which were next examined, were found to be little if at all different from the horny stems of the *Gorgoniæ*. And the various Sponges, which were afterwards subjected to experiment, were proved to be completely formed by the same membranaceous or horny substance, which became varied by the modifications of a more delicate construction, rather than by any essential difference in composition.

This series of experiments terminated with an examination of a few species of *Alcyonium*, namely, *asbestinum*, *Ficus*, and *arboreum*; all of which were found to be composed of a soft, flexible, membranaceous substance, very similar to the cortical part of some of the *Gorgoniæ*, (such as *Gorgonia suberosa*,) and in like manner slightly hardened by carbonate, mixed with a small portion of phosphate of lime.

From what has been said, there is reason to conclude, that the varieties of bone, shell, coral, and the numerous tribe of Zoophytes with which the last are connected, only differ in composition by the nature and quantity of the hardening or ossifying principle, and by the state of the substance with which it is mixed, or connected. For the gluten or jelly which cements the particles of carbonate or phosphate of lime, and the membrane, cartilage, or horny substance, which serves as a basis, in and upon which the ossifying matter is secreted and deposited, seem to be only modifications of the same substance, which progressively graduates, from a viscid liquid or gluten, into that gelatinous substance which has so often been noticed, and which again, by increased inspissation, and by the various and more or less perfect degrees of organic arrangement, forms the varieties of membrane, cartilage, and horn.

I shall now attempt to prove what I have here asserted, or at least assign the reasons which induce me to adopt this opinion; but, in so doing, I am compelled, from the close connection of the subject, to anticipate the general result of part of a series of experiments, made with a view to investigate the nature and composition of membrane.

To enter into a minute detail of these experiments, would far exceed the limits of a paper like the present; I shall therefore only mention, in a concise manner, the results of those which the subject immediately requires to be brought forward.*

The method which first presents itself in such an investigation, is, the comparative analysis of the different substances, so that their relative proportions of carbon, hydrogen, and azote, should be precisely determined; but, when it is recollected, how long a time would be requisite for making such an immense series of analyses, and how much animal substances are subject to be modified by situation in the body, by age, and by the degree of health of animals, and also that the nature of these, and even that of the unorganised bodies, does not always merely depend on the proportion of the constituent principles, but likewise on the degree and mode of combination to which these principles are subjected; I say that when all this,

* These are the experiments to which I alluded in my former paper, and which I began at the request of my friend Mr. HOME, soon after the experiments on the enamel of teeth, &c.

and the plan of the present paper, is considered, I flatter myself that I shall not be censured as hasty or negligent, if at this time I prefer a comparison of the chemical properties of the bodies in question, with those of other substances, which (although not elementary) may be regarded as primary animal compounds; and, when the subject is viewed in its full extent, the mode which I have adopted will, perhaps, be deemed that which is the most satisfactory.

§. III. OBSERVATIONS ON THE COMPONENT PARTS OF MEMBRANE.

In relating the preceding experiments, I have had frequent occasion to remark, that a quantity of that animal jelly which is more or less soluble in water, and which is distinguished by the name of *gelatin*, was obtained from many of the marine bodies, such as the Sponges, the *Gorgoniæ*, and others; but, in the experiments made expressly to investigate the composition of membrane, it still more frequently occurred; and although in many cases, either from the small quantity of the body under examination, or from the very small portion of gelatin thus obtained, I was obliged to content myself with ascertaining the presence of it, by the test of the tanning principle, and by nitro-muriate of tin;* yet, in other experiments, when the solutions of gelatin were gradually reduced by evaporation, I

* Nitro-muriate of tin has been proposed as a test for the tanning principle; and the experiments contained in this paper prove, that it may also be employed with much utility, to ascertain the presence of gelatin, and of certain modifications of albumen.

had opportunities of frequently observing the various degrees of viscidity and tenacity which characterize mucilage, size,* and glue.

The difference in the viscidity and tenacity of the varieties of these substances, is evidently an inherent quality, and not caused by the degree of mere inspissation: if this was the case, mucilage, size, and glue, when dry, would be of an equal quality, which is, however, contrary to daily experience; for the varieties of glue are not of equal tenacity. And it is well known, that glue made from certain parts of animals, such as the skin, is more tenacious, and of a better quality, than that which is made in some places from feet and sinews.

Moreover, when even the same part is employed, which has been taken from two animals of the same species, an evident difference is found, according to the comparative age of the animals; for the best and strongest glue is always obtained from the more aged animals, in whom the fibre is found to be the most coarse and strong. But a longer continued boiling appears requisite in order to extract it; and the more viscid glues are obtained, from the substances which afford them, with greater difficulty than those of a less viscid quality, which may more properly be called size: this difference is to be observed, when muscle is boiled with repeated and frequent changes of water.

Gelatin thus obtained, whether in the state of mucilage, size, or glue, when completely dried, is affected by water according to its degree of viscidity: for, when cold water is poured

* The term size is employed, throughout this paper, to denote that modification of gelatin which appears to be intermediate, between mucilage and the most viscid and tenacious gelatinous substances or glues. The weaker kinds of glue may therefore come under this denomination.

on dry mucilage, it dissolves it in a short time; but, if cold water is poured on those varieties of gelatin which, when dissolved in a proper quantity of boiling water, would, by cooling, form jellies more or less stiff, it acts on them in different degrees, not so much by forming a complete solution, as by causing them to swell and become soft; so that, when a cake of glue has been steeped three or four days in cold water, if it swells much without being dissolved, and, when taken out, recovers its original figure and hardness by drying, such glue is considered to be of the best quality.

I shall soon have occasion to notice, in another place, the effects of acids and of alkalies on gelatin; it will therefore here be sufficient to observe, that as it is soluble in acids, so, if dry mucilage, dry size,* and dry glue, are steeped in nitric acid diluted with three or four parts of water, they will be progressively dissolved, according to the degree of viscidity by which they are separately distinguished.

When the solutions of these substances in water were examined by the tanning principle, and by nitro-muriate of tin, I have found that animal mucilage is more immediately affected by the latter than by the former; while the solutions of size and of glue are equally acted upon by both. And, when gold dissolved in nitro-muriatic acid was added to the solutions of mucilage, size, and glue, the gold was reduced to the metallic state in a few hours, not only on the surface, where it formed a shining metallic pellicle, but also on the sides of the glass, which were thinly coated with a deep yellow sediment, which, like leaf gold, appeared of a fine pale green, when held between the eye and the light.

* Gelatin obtained from eel-skin, evaporated to dryness.

The animal mucilage which I chiefly employed in these experiments, was obtained from the *Corallina officinalis*, as I found it to be pure, and not partly modified into gelatin or animal jelly.* But Mr. BOUVIER asserts, that he obtained the latter substance; † and this appears to me very probable; for mucilage may predominate in this coralline at one period, and gelatin or jelly at another, just as is found to be the case with other animal substances; for it is known, that in young animals mucilage is abundant, and becomes diminished as these increase in growth and age. Hence there is every reason to conclude, that the substance which in the very young animals was at first mucilaginous, becomes progressively more viscid, and assumes the characters of gelatin; which, as animals increase in age, is known to become more and more viscid, as has been already mentioned in the foregoing pages. I am inclined, therefore, to consider mucilage as the most attenuated, and as the lowest in order, among the modifications of gelatin.

As the qualities of gelatin are so various, so the properties of the substances in which it is present as a component part, are much influenced by it; and when, for example, the skins of different animals were compared, I have always found that the most flexible skins afforded gelatin more easily, and of a less viscid quality, than those which were less flexible, and of a more horny consistency.

* By this I mean, that the mucilage had not acquired the degree of viscidity requisite to form a gelatinous substance. The expression which I have employed, is not therefore to be understood as alluding to any essential difference in composition, but only to denote some variation in the degree of consistency; for the whole may be comprehended under the term gelatin, of which, mucilage may be regarded as one extreme, and the strongest and most viscid glue as the other.

† *Annales de Chimie.* Tom. VIII. p. 311.

The skin of the eel possesses great flexibility; and it affords gelatin very readily, and in a large proportion. The skin of the shark also, which is commonly used by cabinet makers to polish their work, was in like manner, for the greater part, soon dissolved, and formed a jelly, like the former. The epidermis or cuticle of these skins, (which is very thin and tender,) although not soluble, was reduced into small particles by violent ebullition; and the spiculæ on the shark's skin were also separated.

The skins of the hare, rabbit, calf, ox, and rhinoceros, were examined in a similar manner, and with the like results; but the gelatin obtained from the hide of the rhinoceros, (as far as the smallness of the piece of skin would allow me to determine,) appeared to be the strongest and most viscid. In every one of these experiments, the true skin or cutis was principally affected, it being completely soluble (as Messrs. CHAPTAL and SEGUIN have well observed) by long boiling; but that of the rhinoceros far exceeded the others in difficult solubility. The cutis of these skins, when first boiled, swelled and appeared horny; it was then gradually dissolved; but in the cutis of the rhinoceros a few small filaments remained, which at length contracted and adhered to the cuticle.

The cuticle of the different skins was softened, but not dissolved; and, as the cutis seems to be essentially formed of gelatin,* so the cuticle appears to contain it, although but in a small proportion: it is, however, necessary to its flexibility; for when, after long boiling, the cuticle of these skins was dried,

* The cartilages of the articulations are also completely soluble when long boiled with water; but this by no means happens when other cartilages are thus treated.

it became a brittle substance, which was easily reduced to a powder.

Hair was much less affected than either of the abovementioned substances; and this, with others in some measure similar, I shall now more particularly notice.

The substances to which I allude, are hair, feather, horn, horny scale, hoof, nail, and the horn-like crust which covers some insects and other animals, such as the scorpion and the tortoise. These I shall now mention, in as concise a manner as the subject will allow.

When hair of various qualities, and taken from different animals, was long digested or boiled with distilled water, it imparted to the water a small portion of gelatin, which was precipitated by the tanning principle, and by nitro-muriate of tin; and, when the hair had been thus deprived of gelatin, and was subsequently dried in the air, the original flexibility and elasticity of it was found to be much diminished, so that it easily gave way, and was broken.

This effect, Mr. ACHARD has also noticed;* and I am induced to believe (from various experiments which I have made on these substances) that the hair which loses its curl in moist weather, and which is the softest and most flexible, is that which most readily yields gelatin; and, on the contrary, the hair which is very strong and elastic, is that which affords it with the greatest difficulty, and in the smallest proportion.

These remarks have moreover been corroborated, by the

* "La perte de la partie gélatineuse ôtant aux cheveux leur souplesse, il s'ensuit "que c'est aux parties gélatineuses qui entrent dans la composition des cheveux qu'ils "doivent leur pliant et leur élasticité."—*Examen chimique des Chevex. &c. Memoires de l'Acad. de Berlin.* Tom. XXXVIII. p. 12.

assertion of a considerable hair merchant in this metropolis,* who, during a long experience of upwards of forty years, has always found, that hair of the first named quality cannot be boiled an equal time with those last mentioned, without suffering material injury in strength and flexibility.

Feather, digested in boiling distilled water, during ten or twelve days, did not afford any trace of gelatin by the test of the tanning principle; but nitro-muriate of tin produced a faint white cloud.

The same was observed when quill was thus examined.

Shavings and pieces of the horns of different animals were next subjected to experiment, and all afforded small quantities of gelatin, which was precipitated by the tanning principle, and by nitro-muriate of tin; and it was generally observed, that the more flexible horns yielded the largest quantity of gelatin, with the greatest ease; and, (like the substances already mentioned,) when deprived of it, and suffered to dry spontaneously in the air, they became more rigid, and were easily broken.

The horns which I mean, are those of the ox, ram, goat, and chamois, which, in my former paper I considered, as I do now, to be perfectly distinct from the nature of stag's or buck's horn; for this last is as different from the former in chemical composition, as it is in construction: like bone, it affords much phosphate of lime, and, like bone, it affords a large quantity of gelatin; and it is not a little remarkable, that phosphate of lime is generally accompanied by gelatin, as in stag's horn, bone, ivory, &c. on the contrary, when carbonate of lime is the hardening substance, as in shells, madrepores and millepores, no gelatin can be discovered; for I have frequently digested these

* JOHN COLLICK, Esq. of St. Martin's Lane.

substances many days in boiling distilled water, (after having reduced them to a coarse powder, that they might present a larger surface,) but I never could, by any test, discover the slightest vestige of gelatin. The horns therefore which were first mentioned, are very different from the composition of stag's horn, and yield gradually, and with great difficulty, only a small quantity of gelatin.

Horny scale was next examined; but I shall first here request permission to make a digression in respect to the scales of fish, which I had not examined when my paper on shell and bone was read.

As the scales of fish, when viewed by a microscope, and according to the observations of Mr. LEEUWENHOEK, appear to be formed of different membranaceous laminæ, and as they exhibit the colour and lustre of mother of pearl, it might be expected, that they should prove to be of a similar nature with the substance of stratified shells, or, in other terms, that they should consist of membrane and carbonate of lime.

But, when scales perfectly clean, and separated from the skin of different fish, (such as the salmon and carp,) had been immersed during four or five hours in diluted nitric acid, till they became transparent, and perfectly membranaceous; the acid liquor, being then saturated with pure ammoniac, afforded a copious precipitate, which was proved to be phosphate of lime.

The spiculæ of the shark's skin, formerly mentioned, were found to be of a similar composition; and we may therefore regard the spiculæ and scales of fish as true bony substances, in which the membranaceous part is more predominant than in common bone.

I fully ascertained, that the phosphate of lime was afforded by these substances only; for, when the different skins from which these scales and spiculæ had been taken, were separately examined in the like manner, no phosphate of lime was obtained.

In addition to this I must observe, that the silver or pearly hue of pearl, mother of pearl, and of fish-scales, is only assisted and modified by the relative degrees of opacity produced, in mother of pearl and in pearl, by the interposition of the particles of carbonate of lime, and in the scales by phosphate of lime; for this peculiar lustre principally resides in the membranaceous part, and remains with it when the acetous or muriatic acids are employed as menstrua, but is completely destroyed by the nitric acid.

The horny scales of serpents, lizards, and such like animals, differ from the foregoing; as all of those which I have examined, consist merely of the membranaceous or horny substance, in a more or less indurated state, and appear to be devoid of phosphate of lime, as an ossifying matter.

Horny scales in general, (and the scales of the *Manis pentadactyla* may be mentioned as an example,) afford but very slight traces of gelatin after being long boiled in distilled water; and this small portion of gelatin can only be discovered by the tanning principle, and by nitro-muriate of tin, unless a very large quantity of the scales has been employed.

Human nail digested in boiling distilled water during several days, was only softened; and, like quill, afforded a slight cloud, by the addition of nitro-muriate of tin.

Shavings of ox's hoof, when long digested as abovementioned, afforded a liquor which, in like manner, was only made slightly turbid by nitro-muriate of tin.

Nail and hoof, when long boiled, became of a much darker colour.

The horn-like crust which covers certain insects and other animals, was subsequently examined; the experiments were principally made on the plates which covered the body of a large African scorpion, and on the common tortoise-shell of the shops.

The plates taken from the scorpion were not apparently affected, although digested for a long time in boiling distilled water.

The tanning principle produced no alteration, when added to the water; but a faint white cloud appeared, upon the addition of nitro-muriate of tin.

Tortoise-shell, in thin slips and shavings, was digested in a similar manner during three weeks; but it was only slightly softened; and the water, which had acquired a brownish colour, was but little affected, even by nitro-muriate of tin, which however formed a white cloud.*

From some previous circumstances, which need not here be mentioned, I was lastly induced to make some similar experiments on albumen; and, as that of the blood is mixed with gelatin, and with the substance called fibrin by the chemists, which in chemical properties appears to be the same as muscular fibre, and as it is with some difficulty that the albumen can be exactly separated from these substances, I preferred the albumen of eggs, as being pure and unmixed; and, in order that it might be brought into a state in some measure similar to the bodies lately examined, (by which I mean simple inspissation,) I dried it, after coagulation, in a vessel which was

* The crust which covers insects like the scorpion, appears in every respect to be similar to tortoise-shell.

heated to 212° of FAHRENHEIT, till it became perfectly hard, brittle, yellow, and semi-transparent, like horn.

The albumen, in this state, was digested during eight days in boiling distilled water, which was occasionally renewed, in proportion to the evaporation.

In a few hours after the commencement of the digestion, the transparent horny pieces of albumen were softened, and became white and opaque, exactly like albumen recently coagulated; but, after this, no farther change was observed.

At the end of eight days, the water in which the albumen had been digested was examined, and was found exactly to resemble that afforded by quill, nail, and tortoise-shell; for the transparency of it was not disturbed by the tanning principle, although nitro-muriate of tin produced a faint white cloud.*

As far, therefore, as could be ascertained, by long digestion in boiling distilled water, and by the effects of the re-agents, albumen was proved to be very similar to tortoise-shell, and many of the other substances previously noticed; but the close resemblance, or rather indeed identity, of albumen with those bodies, will be placed in a stronger light, by the enumeration and comparison of their other chemical properties.

As I have, in the former part of this paper, had occasion to mention the gelatin obtained from the Sponges and *Gorgoniæ*, it is not necessary here to repeat those remarks, neither is it requisite that I should enter into any minute account concerning

* When infusion of oak-bark is added to recent liquid albumen, it immediately forms a precipitate; and nitro-muriate of tin does not produce any effect till some hours have elapsed. But after coagulation the reverse takes place; for the water in which coagulated albumen has been long boiled, becomes turbid by the addition of nitro-muriate of tin; and is not in any manner affected by infusion of oak-bark.

the experiments made on bladder, and some other membranes. It may therefore suffice here to observe, that all these bodies afforded more or less gelatin; that, when this was separated, the remaining substance ceased to be tough, or elastic, and was easily torn, like wetted paper; and that, when dry, the sponges, and such membranes as bladder and cuticle, became very brittle, and were shrivelled and curled up, like withered leaves of plants.

But, before I speak of the nature of the substance which thus remained, it will be proper, concisely to notice the effects of acids on the bodies which afford gelatin; and, as the most remarkable effects were produced by nitric acid, I shall to that confine the present observations.

The specific gravity of the nitric acid which I employed in the whole of my experiments, was 1,38; and this acid was diluted with 2, 3, or 4 measures of distilled water, according to the quality of the substance under examination, and the intended time of immersion. But, as an acid too powerful would have frustrated my intentions, I commonly added the acid, by degrees, and at long intervals, to the water in which the substance was immersed; during which time, if any nitrous gas was discharged, more water was added, as this gas was a certain sign that the acid was not sufficiently diluted.

Substances like the *Corallina officinalis*, which contain a large quantity of animal mucilage, or of the least viscid jelly, soon impart it to boiling water.

In like manner, when such substances were steeped in nitric acid diluted with about three measures of water, the mucilage was in a few hours completely dissolved, while the membranaceous part remained untouched.

Pure isinglass dissolved in the diluted nitric acid, formed a pale yellow liquor, which by evaporation became of a deeper colour, and, when nearly dry, was suddenly reduced to a spongy coal. This change was rapid; and was attended with a considerable effervescence, and a copious discharge of nitrous gas, not unfrequently accompanied by sparks, and sometimes flame; arising undoubtedly from nitrate of ammoniac, which was formed towards the end of the evaporation.

The acid solutions of mucilage, isinglass, and pure glue, were changed to a deeper yellow, when saturated by the absorbent earths, by the alkalies, and especially by pure ammoniac. In such cases, little or no precipitate was obtained from pure gelatinous substances; but some faint traces of phosphoric acid were discovered in these solutions.

The effects of the dilute nitric acid on the other various substances which have been mentioned, resembled those now described, and kept pace exactly with those of boiling water; for, when they were immersed in equal quantities of the dilute acid during a given time, the solution of the gelatin took place according to the order observed in those substances, when water was employed.

As an instance of this, two pieces of skin, recently taken from an ox, were subjected to experiment, as follows:

One of the pieces was boiled in water, till the whole of the cutis was dissolved; after which, the cuticle remained, although very feeble in texture, while the hair did not seem to have suffered any material alteration.

The other piece was steeped in nitric acid diluted with about four measures of distilled water. At the end of five days the cutis was dissolved, and the cuticle was become of a loose and feeble texture; but the hair had not suffered any apparent change, excepting that of being slightly tinged with yellow. In both cases, therefore, the effects of boiling water and of acid were similar, and were evidently most powerful on those parts which were the most gelatinous.

As water dissolves mucilage more speedily than size, and this last more readily than strong viscid glue, so are the effects of very dilute nitric acid on the same substances; and, when equal quantities of dried mucilage, of eel-skin glue, and of the strongest glue, were dissolved in equal quantities of the dilute acid, the colour of the solutions was more intense, and the change produced by ammoniac was more visible, according to the order of solubility and of tenacity.

It is well known how readily gelatin is dissolved by the caustic fixed alkalies: when, therefore, the varieties of jelly or glue were added to boiling lixivium of caustic potash, they were soon dissolved; and, if added to saturation, a brownish viscid substance was formed.

I did not observe that any ammoniac was produced, neither was any coal deposited, after long boiling the solution in which there was an excess of alkali.

The viscid matter thus obtained, *did not possess the properties of animal soap;* for it neither formed a permanent lather, when mixed and shaken with water; nor, when saturated with acids, did it afford any precipitate; contrary to what happens, when animal soap is thus treated. But, if the gelatinous substance was not pure; if, for example, any parts of membrane, which are not soluble in water, were present, then, in proportion to the quantity of this substance, the alkaline solution exhibited more or less of the saponaceous characters; but these I never observed when pure gelatin was employed.

Gelatin, according to its quantity and quality, has a powerful influence on some of the physical and chemical properties of the bodies in which it is present; by these properties, I mean flexibility, elasticity, and putrescibility.

So much has been said already, in various parts of this paper, tending to prove how much the degrees of flexibility and elasticity, in various animal substances, depend on their gelatinous part, that little need be added; and, when it is considered, that bodies such as muscular fibre, membrane, sponge, hair, and cuticle, being deprived of gelatin, and dried in the air, become rigid and brittle, no doubt can be entertained but that this arises from the loss of the gelatinous substance; and, as an additional proof, when bodies such as nail, feather, quill, and tortoise-shell (which contain little or no gelatin) are long boiled, and then dried in the air, like the former, they are found to have suffered scarcely any alteration in their respective degrees of flexibility and elasticity.

As to putrefaction, it is obvious to every one, that certain parts of animals are much more susceptible of it than others; and that, when the carcase of an animal begins to putrefy, the most humid and flexible parts are always first affected.

Thus, the viscera, muscles, and cutis, soon suffer a change; while hair, feather, scale, horn, hoof, and nail, remain unchanged, ages after the former have been decomposed; and this is evidently caused by the gelatin and moisture, which are combined in the former, and not in the latter, at least in any notable quantity. I have already mentioned the progressive and comparative effects of boiling water, and of dilute nitric acid, on the skin of the ox; and I have shewed, that while the cutis was completely dissolved, the hair remained untouched. These effects are to be observed, in the same exact order, when a similar piece of skin is exposed to putrefaction; for this commences in, and chiefly affects, the cutis, while the hair is separated, unchanged in its quality. I do not, therefore, hesitate to assert, that the degree of putrescibility in the various parts of animals, depends principally on the presence, and on the quantity and quality, of gelatin; and the skin of the rhinoceros found on the banks of the Vilui, near Yakutsk, was preserved, in all probability, partly by the nature of the climate and soil, and partly by the superior horny quality which it possessed over other skins; for it may be much questioned, whether the hide of an ox or horse, in the same situation, would have escaped putrefaction for so long a period.*

From the preceding observations it appears, that gelatin is a component part of many animal substances.

That it differs in quality, from a very attenuated jelly or mucilage, to that viscid substance called glue; the varieties of which also differ in solubility and tenacity.

That it is present in various proportions; so that certain bodies, such as the cutis, and the cartilages of the joints, are formed by it; while others, like nail, quill, and tortoise-shell, can scarcely be said to contain it.

And that, by its presence, in various states and proportions, it may be regarded (including inherent moisture and organic

* The more viscid gelatinous substances do not appear to be so immediately susceptible of putrefaction as those of the opposite quality; for, when solutions, in water, of animal mucilage, eel-skin glue, and strong glue, were during a certain time exposed under equal circumstances, I found the mucilage to be the first, and the glue the last, which shewed symptoms of putrefaction.

arrangement) as the principal cause of those degrees of flexibility, of elasticity, and of putrescibility, so various in the different parts of animals.*

But, when gelatin has been separated from the different substances, either by repeated boiling with water, or by being steeped in dilute acids, a more insoluble substance remains, of a very different nature, which I shall now proceed to examine.

When a bone or piece of ivory has, by long boiling in

* As gelatin, according to its proportion and quality, appears to produce considerable effects on the parts of animals in which it is present; and, as the gelatin in animal bodies is, in all probability, liable to be changed and modified by morbid causes, it is much to be wished, that gentlemen of the medical profession would ascertain, by experiments, how far the tonic properties of barks depend on the tanning principle.

Mr. BIGGIN has proved, (Phil. Trans. for 1799. p. 259.) that willow bark, and especially that of the Huntingdon or Leicester willow, contains the tanning matter in a considerable quantity; and that the latter, in this respect, even equals, or rather exceeds, that of oak.

My friend, the Rev. THOMAS RACKETT, Rector of Spetisbury and Charlton, in Dorsetshire, has employed, in those parishes, the bark of the common willow with great success, as a tonic and febrifuge. Moreover, Mr. WESTRING, of Norrköping, has observed, (*Annales de Chimie*. Tom. XXXII. p. 179.) that those species of *Cinchona* which contain the tanning principle in the greatest quantity, are the most efficacious in fevers; and that the *Cinchona floribunda*, which contains scarcely any tanning matter, is destitute of the abovementioned beneficial effects. Mr. WESTRING therefore, with great apparent reason, believes, that the relative effects produced by the different species of *Cinchona*, when employed in medicine, are in proportion to their tanning power, or the quantity of tanning principle contained in them.

If any one should be induced to make experiments on the tonic effects of the tanning principle, it is to be hoped that some attention would also be paid to the medicinal properties of nitro-muriate of tin, of which, at present, I believe little or nothing is known.

water, been deprived of a great part of its gelatin, and is afterwards steeped in a dilute acid, the ossifying substance is dissolved, and the cartilage remains, retaining the figure of the original bone; or, if a similar bone or piece of ivory, which has not been boiled, is steeped in a dilute acid, (especially nitric acid,) the ossifying substance is dissolved, and, at the same time, but more slowly, the gelatin is separated, and causes the liquor to become yellow, when the phosphate of lime is precipitated by ammoniac.

The cartilaginous body which remains, after the gelatin has been thus separated, is not easily soluble in dilute acids, for (according to its texture) many weeks, and even months, may elapse, before a small part is taken up; but, in concentrated nitric acid, or in boiling dilute acid, it is rapidly dissolved, as I shall soon have occasion to mention.

This substance, when dry, is semi-transparent, like horn, and more or less brittle.

It is the predominant and essential part, in the tissue or web of membrane, cartilage, sponge, the horny stems of *Gorgoniæ*, horn, hair, feather, quill, hoof, nail, horny scale, crust, and tortoise-shell; and, although of similar chemical properties, yet in consistency it varies, from a tender jelly-like substance, to a completely formed membrane, or to an elastic, brittle, and hard body, like tortoise-shell.*

* These bodies, especially tortoise-shell, appear to be formed (as far as organic arrangement is concerned) in the way of *stratum super stratum*. This structure is peculiarly to be discovered after long maceration in diluted nitric acid; for then, tortoise-shell appears to be composed (like the black polished *Gorgonia*) of membranaceous laminæ; and the varieties of horn differ only by a tendency to the fibrous organization.

Experiments were made separately, on each of the bodies above enumerated; but, as I did not find any essential difference in the results, I shall include the whole under the following observations.

1. When distilled, a small portion of water, some carbonate of ammoniac, a fœtid empyreumatic oil, carbonated hydrogen gas, carbonic acid gas, and prussic acid, were obtained.

2. A spongy coal, of a gray metallic lustre, remained: this, by incineration, afforded a very small residuum, which was not always similar in quantity, even in portions of the same substance; for, 500 grains of tortoise-shell, taken from different samples, afforded from $\frac{1}{4}$ of a grain to 3 grains of residuum, which consisted of phosphate of lime, and phosphate of soda; sometimes also a little carbonate of lime was present; but I do not believe these to be essential ingredients.

3. When boiled many days in distilled water, the substance was softened; and the water became slightly turbid with nitro-muriate of tin; but no effect was produced by the tanning principle.

4. Muriatic and sulphuric acids had little effect, unless heated; and the same was the case with nitric acid much diluted, or in the state proper to extract and separate gelatin; but, if the immersion in the dilute acid was continued during some weeks, the acid gradually acquired a yellow tinge, and, when saturated with ammoniac, became of a deeper colour, without having its transparency disturbed.

5. The substance which had thus been long steeped in the acid, was much softened, was become more transparent, and, from being horny, was now more like a cartilaginous substance: when taken out of the acid, if it was immediately

steeped in pure ammoniac, it changed to a deep orange colour, inclining to blood red; it was gradually and silently dissolved, without any residuum, and a deep orange or yellowish brown coloured liquor was formed.

6. Or, when taken out of the acid, if it was first well washed in distilled water, and then boiled, it was also dissolved, and formed a pale yellowish solution: this, by evaporation and cooling, became a jelly, which was again soluble in boiling water; and was precipitated, like gelatin, by the tanning principle, and, more slowly, by nitro-muriate of tin.

7. If the nitric acid in which the substance was immersed was not sufficiently diluted, or if heat was applied, the whole was rapidly dissolved, with a considerable effervescence, and discharge of nitrous gas.

8. This solution was yellow, like the former, the colour being intense, in proportion to the quantity dissolved; and it was also changed to a deep orange or yellowish brown by the addition of ammoniac, without depositing any precipitate, unless a large quantity had been dissolved.

9. The nitric solutions of this substance, when evaporated, afforded much the same appearances as those of gelatin, but the coal which remained was less spongy.

10. This substance (whether of sponge, horn, quill, hair, nail, or tortoise-shell, &c.) was strongly distinguished from gelatin, by the effects produced when boiled with caustic fixed alkali; for animal soaps were formed, exactly similar in every property excepting colour, and the whole of the original substance was completely dissolved.

11. During the process, a considerable quantity of ammoniac

was discharged; and, if the alkali was in excess, some coal was deposited.

12. When the animal soap was dissolved, diluted with distilled water, and filtrated, if an acid (such as the acetous, or muriatic) was added, a copious precipitate was obtained, which was re-dissolved by an excess of acid.

13. This precipitate, being collected upon a filter, appeared at first like a yellow or brownish viscid substance, which, when dry, was like a thick coat of varnish, or dried white of egg, and in like manner was brittle, and broke with a glossy fracture.

14. It burned like quill or tortoise-shell, leaving a spongy coal; and, when distilled, afforded products like those obtained from the bodies abovementioned.

15. It was not readily soluble in dilute acids; and was acted upon by nitric acid and ammoniac like the substances from which it had been obtained; the properties also of its solutions in nitric acid and ammoniac were similar.

16. With caustic lixivium of potash it readily combined, and again formed animal soap.

17. It was not quite so insoluble in boiling water as quill or tortoise-shell; and the water in which it had been boiled was not only made turbid by nitro-muriate of tin, but yielded a precipitate when infusion of oak-bark was added, after the manner of gelatin.

These experiments proved, that this precipitate was the same as the original substance from which it had been obtained; and that the only change it had suffered, was that of being rendered rather more soluble in boiling water.

The whole series of experiments on the various bodies lately enumerated, convinced me moreover, by the similarity of results, that they essentially consisted of one and the same substance, modified in texture by the degrees of organic arrangement, and by the occasional presence, and different proportion and quality, of gelatin.

But the difference in chemical properties shewed, that this last mentioned substance (I mean gelatin) was quite distinct from that which is now under examination; and, from the resemblance of certain effects observed when quill and tortoise-shell were compared with inspissated albumen, by being long digested in boiling water, I was induced to make a series of comparative experiments upon albumen, similar in every respect to those which have been so lately described, of which the following are the results.

1. By distillation, the coagulated dry semi-transparent albumen, afforded products exactly similar to those obtained from tortoise-shell, and the other substances which have just been examined.

2. A spongy coal remained, of very difficult incineration; as towards the end of the process it appeared vitrified, and glazed with a melted saline coat, which was, however, easily dissolved by water.

The residuum was again exposed to a long continued red heat, and again treated with water, till, at length, a few scarcely visible particles remained; which, as far as such a small quantity would permit to be ascertained, proved to be phosphate of lime.

The portion dissolved by water (which was by much the most considerable) consisted principally of carbonate, mixed with a small quantity of phosphate of soda.

3. When steeped in dilute nitric acid, it was not soon affected;

but, after about four weeks, the acid began to be tinged with yellow, which gradually became deeper in the course of three months; the albumen, however, although less transparent, was but little diminished.

The yellow acid solution, when saturated with ammoniac, changed to a deep orange colour, and remained transparent.

4. The albumen which had been thus steeped in the dilute nitric acid, was immediately immersed in ammoniac; which changed it to a deep orange colour, inclining to a blood red, and gradually dissolved it, without any apparent residuum.

This solution was of a deep yellowish brown.

5. If the albumen, instead of being immersed in ammoniac, was washed, and then boiled with distilled water, it was dissolved, and formed a pale yellow liquor, which, by evaporation, formed a gelatinous mass; this, being dissolved again in boiling water, was (like gelatin) precipitated by the tanning principle, and more slowly by nitro-muriate of tin.

6. By concentrated nitric acid, or by the dilute acid when heated, albumen was speedily dissolved, with much effervescence, and a copious discharge of nitrous gas.

7. This solution was like that of tortoise-shell, and the other substances mentioned in the former experiments.

8. When evaporated, it afforded similar results.

9. Albumen, like tortoise-shell, quill, and nail, was dissolved by boiling lixivium of caustic potash, and formed animal soap.

10. In like manner also, a considerable portion of ammoniac was discharged; and, if the alkali was in excess, some coal was deposited.

11. The animal soap obtained from albumen, when dissolved

in water, yielded a precipitate, by the addition of acetous or muriatic acid; and the precipitate was re-dissolved, when the acid was added to excess.

12. This precipitate, when collected on a filter, appeared more saponaceous, and less viscid, than that obtained from the substances lately examined.* When gently heated, some oil flowed from it; after which, a brownish viscid substance remained, similar in its properties to that which was obtained from the animal soap made by tortoise-shell, and the other bodies.†

13. It may not be improper here to repeat, that inspissated albumen, long boiled with distilled water, was not apparently diminished; but the water (like that in which tortoise-shell, quill, or nail, has been boiled) had acquired the property of becoming white and turbid, when nitro-muriate of tin was added, although it was not changed by the tanning principle.

To this also may be added, that the water in which tortoise-shell, nail, and albumen, had been boiled, became in some measure putrid in a few days, and emitted an offensive smell.

I am not inclined, however, to regard this as a proof that any gelatin had been separated from these bodies by means of boiling water, but rather that inspissated albumen, tortoise-shell, *&c.*

* This precipitate, when obtained from different substances, such as hair, wool, and muscular fibre, appeared in some cases more, and in others less viscid, although similar in every other property.

It will be proper also here to observe, that the saponaceous solutions were always filtrated, before the addition of the acids.

† The yolk of eggs, when boiled with caustic lixivium of potash, forms a pale olive-coloured concrete animal soap, which, when dissolved in water, and saturated with muriatic acid, is precipitated in the state of mere fat.

Yolk of egg, by incineration, affords a small portion of phosphate of soda and of lime.

are substances really soluble, although in so slight a degree as to approach insolubility; and that thus the prevalent opinion has arisen concerning the insolubility of coagulated albumen in boiling water.

Neither is the putrefaction of the water in which the bodies abovementioned have been boiled, a proof that any other than their real substance has been dissolved; for this putrefaction appears to depend on its attenuated and diluted state, more than on any other cause. Tortoise-shell, nail, quill, and similar bodies, certainly are not liable to putrefaction; neither is albumen, when in the inspissated semi-transparent state.

This last substance also, when merely coagulated, does not easily putrefy; for I kept it, when it was soft, white, and coagulated, in water, during the whole of the month of last April, without finding that it became really putrid: towards the latter part of the time, it had rather a disagreeable smell; still, however, it was far from being absolutely putrid.

But albumen which has not been coagulated, or which has been diluted and shaken with a quantity of cold water, begins in a very few days to be putrid; liquid albumen, therefore, enters easily into putrefaction, although it is the reverse with that which is dense and solid: and, from a comparison of the preceding experiments upon tortoise-shell, quill, nail, *&c.* with those made on albumen, I am induced to believe, that the former bodies are essentially composed of albumen, modified by the various effects of organization, and reduced to a state of density far exceeding that which is produced by simple inspissation.

And, although the bodies, which of late have been particularly mentioned, appear to consist principally of albumen, with sometimes the addition of gelatin in different proportions, yet, as in certain membranes and such like substances, portions of muscular fibre were at times found joined or interwoven; and as muscle, ligament, and tendon, seem to glide almost imperceptibly into each other, I was almost unavoidably induced to make some experiments on muscular fibre.

The muscular fibre on which the greater part of these experiments was made, was that of beef; and, in order to separate the liquid albuminous part or lymph as much as possible, a quantity of lean muscle of ox beef, cut into small thin pieces, was macerated during 15 days in cold water, and was subjected to pressure each day, when the water was changed. The weather was very cold; and the maceration was continued to the end of the 15th day, without any sign of putrescency.

The shreds of muscle (amounting to about 3 pounds) were then boiled with about 6 quarts of water, during 5 hours; and, the water being changed, the same was repeated every day, during the course of three weeks; at the end of which time, the water afforded only slight signs of gelatin, when infusion of oak-bark, or nitro-muriate of tin, was added. After this, the fibrous part was well pressed, and was dried by the heat of a water bath.

Some of the muscular fibre thus prepared, was steeped in nitric acid diluted with three measures of water, during 15 days. The acid acquired a yellow tinge, and possessed all the properties of the nitric solutions of albumen.

The fibre which had been thus steeped in the acid, was (when washed) dissolved by boiling water, and by evaporation became a gelatinous mass; which, being again dissolved in boiling water, was precipitated by infusion of oak-bark, and, more slowly, by nitro-muriate of tin, like the albuminous substances, when treated in a similar manner.

When the fibre which had been steeped in the acid was immersed in ammoniac, it was not completely dissolved, like albumen, but afforded a residuum, which will soon be noticed. The greater part was, however, thus dissolved; and formed a deep orange or yellowish brown solution, similar in properties to that of albumen.

When boiled with lixivium of caustic potash, this muscular fibre was completely dissolved; ammoniac was discharged, and animal soap was formed; which, being diluted with water, and saturated with muriatic acid, yielded a precipitate, similar in every property to that which had been obtained from the animal soaps formerly mentioned, excepting, that it sooner became hard and glossy, when exposed to the air.*

Muscular fibre, when prepared as already mentioned, so as (by long maceration, and subsequent boiling, with frequent change of water) to be very nearly deprived of the whole of its gelatinous part, is not easily brought into the putrid state. A small quantity was kept moistened with water, during the whole of last April; in the course of which time, it acquired a musty but not a putrid smell; neither were the fibres reduced

* In respect to œconomical purposes, it may be proper here to observe, that all animal substances whatever, (exclusive of carbonate and phosphate of lime,) may be converted into two substances of much utility, namely, glue, (under which term I include all the varieties mentioned in this paper,) and soap; with the additional advantage, that those parts which would be rejected in making the one, are the most proper to prepare the other.

The offensive smell of CHAPTAL'S soap is considered as an objection; but this may be removed, by exposing the soap for some time, in flat vessels, to the air; after which, it may be reduced to the proper degree of consistency, by a second boiling.

to a pulpy mass.* I am inclined therefore to suspect, that strong and completely formed muscular fibre, considered as a distinct substance, is not of easy putrescibility; and that the readiness with which muscle in general enters into putrefaction, is principally owing to the gelatin, which is combined and mixed with it, in a large proportion, as a component part, and which, with the natural quantity of moisture, is requisite to give the fibre a proper degree of toughness and flexibility.

The residuum afforded by muscular fibre which had been long steeped in dilute nitric acid, and afterwards immersed in ammoniac, consisted principally of fat, mixed with a small portion of the fibre which had not been sufficiently acted upon by the acid; and little or no earthy matter was thus obtained.

But, when the prepared muscular fibre was dissolved in boiling nitric acid, a complete solution, resembling that of albumen, in its general properties, was formed; and some fat floated, in drops, at the top of the liquor.

Ammoniac was then added, so as to super-saturate the acid, and produced the same effects as on the nitric solutions of albumen, excepting, that a copious white precipitate was obtained.

This precipitate, while moist, was agitated with a quantity of acetous acid, which dissolved, and separated, a small portion of phosphate of lime; but the remainder, and by much the greatest part of this precipitate, was scarcely attacked, even when the acid was boiled.

When exposed to a red heat, it became dark gray, and then

* A portion of this muscular fibre was kept under water during two months; it did not however become putrid, nor was it converted into that fatty substance which is obtained from recent muscle, under similar circumstances.

nearly white; after which, it was in the state of carbonate of lime.

Another part was dissolved in nitric acid, and lime was precipitated by carbonate of soda. The slight excess of the latter was then saturated by acetous acid; and the whole was boiled, to expel the carbonic acid; after which, the liquor, from its effects on solutions of lime, barytes, *&c.* evidently contained oxalic acid in solution: the precipitate was therefore oxalate of lime, mixed with a very small quantity of phosphate of lime.

200 grains of the dry muscular fibre, dissolved and boiled with nitric acid, afforded 17 grains of this precipitate.

Although it is known that the gelatinous liquor obtained from muscle by boiling water, contains phosphate of soda, and of lime, yet I did not imagine that the greater part of the latter could be so completely separated.

I therefore, in some measure, repeated the experiment, on the muscle of veal; and (as I expected) found phosphate of soda, and of lime, in the liquor. But, when the muscle was afterwards dissolved in boiling nitric acid, and the solution was saturated with ammoniac, I was surprized to find that, although the same change in colour was produced as in all the former experiments, the liquor remained transparent; and, even after several days, only a few scattered particles appeared at the bottom of the vessel.

Another experiment was made, on the recent muscle of mutton; but this was immediately dissolved in nitric acid, without being previously boiled in water. The fat being separated, the solution was, as before, saturated with ammoniac; and, as usual, became of a deep orange colour, or yellowish brown: in a few hours also, a small quantity of a white precipitate subsided.

This precipitate, however, was completely and readily soluble in acetous acid; and in every respect proved to be phosphate of lime.

Before I proceed, it will be proper to observe, that the liquor from which the above precipitate was separated, as well as those afforded by the muscle of veal, by the prepared muscle of beef, by the solutions of tortoise-shell and of albumen, in boiling nitric acid, subsequently saturated by ammoniac, all contained a considerable portion of uncombined oxalic acid, which was separated by acetite of lime, and of lead. But I did not find oxalic acid in the solutions formed by immersing these bodies, for a long time, in cold and dilute nitric acid; neither did I find oxalic acid in solutions made by dissolving these substances in boiling muriatic acid. It is evident, therefore, that the oxalic acid observed in the above experiments, was a product of the operations, and not an educt of the substances.

We may conclude, from the experiments on the muscular substances which have been lately mentioned, that they contain lime, in various proportions, and in two different states, viz. carbonate and phosphate; and that the greater part of the latter is gradually separated, in conjunction with the gelatin, by means of boiling water. I would not however have it understood, that phosphate of lime is an essential ingredient in gelatinous substances; for, on the contrary, isinglass, which is a perfectly gelatinous body, affords but a mere visible trace of it. The muscular fibre of beef appears to have been nearly deprived of its phosphate of lime, by the long continued and repeated boiling in water to which it had been subjected; but still so large a quantity of lime remained, that when oxalic acid was formed by the action of the boiling nitric acid, it combined with the lime, and formed an oxalate, which amounted to 17 grains, from 200 grains of the dry muscular fibre, dissolved in nitric acid, and precipitated by ammoniac.

I do not know what quantity of phosphate of lime was separated with the gelatin, as I was then only intent on preparing the fibrous part of the muscle; but, from the quantity of lime which remained, and which afterwards combined with the oxalic acid, it is evident, that in the muscle of beef there is a considerable portion of earthy matter; and as, by the experiment on the muscle of veal, scarcely any precipitate was obtained after it had been boiled, and as but a small portion of phosphate of lime was present in the gelatinous liquid, it appears that, in this muscle, the whole of the small portion of lime which it contained was in the state of phosphate; and this being nearly separated, there did not remain any part of uncombined lime, or carbonate of lime, which, by uniting with the oxalic acid, (subsequently produced,) would form an oxalate; and as lime, in the states of phosphate and carbonate, is so much more abundant in the muscle of beef than in that of veal, we may infer, that the earthy matter is more abundant in the coarse and rigid fibre of adult and aged animals, than in the tender fibre of those which are young; and this seems to be corroborated, by the tendency to morbid ossification, so frequently observed in aged individuals of the human species.

Gelatin, albumen, and muscular fibre, not only differ very much from each other by the relative quantity of their saline or earthy residua, but also by the proportion of one of their essential and elementary principles, namely, carbon. 500 grains of isinglass, made perfectly dry by distillation, yielded 56 grains of coal, from which, 1,50 grains of earthy residuum, obtained by incineration, being deducted, the proportion of coal appears to have been 54,50 grains.

500 grains of dry albumen, afforded 74,50 grains; and, as the saline residuum amounted to 11,25 grains, the quantity of mere coal was 63,25 grains.

500 grains of tortoise-shell, yielded 80 grains of coal; from which, 3 grains of earthy matter being deducted, 77 grains remain, for the proportion of coal.

And 500 grains of the dry prepared muscular fibre of beef, when distilled, left 108 grains of coal, which, by incineration, afforded 25,60 grains of earthy residuum; the coal may therefore be estimated at 82,40 grains.

There appears much reason therefore to believe, that the gelatinous substances and muscular fibre, differ from simple and unorganized albumen, by a diminution of the carbonic principle in the one, and by an excess of it in the other; and as, in vegetables, the fibrous part is that which contains the largest proportion of carbon, so, in respect to the other animal substances, muscular fibre appears to contain the greatest quantity of it.

The nature of the residua obtained by the incineration of the substances lately mentioned, also deserves to be noticed.

Only 1,50 grain was obtained from 500 grains of isinglass; and, as far as the quantity would allow, was proved to be phosphate of soda, mixed with a very minute proportion of phosphate of lime.

The 3 grains afforded by tortoise-shell, consisted of phosphate of soda and of lime, with some traces of iron: it is probable, that the latter was accidentally present.

The prepared muscular fibre of beef yielded 25,60 grains; the greatest part of which was carbonate of lime, mixed with some pure lime, and a small portion of phosphate: there can be no doubt but that the latter would have been more abundant, had it not been for the repeated boilings to which the muscular fibre had been subjected.

The recent muscles of veal and mutton were with great difficulty reduced to ashes; for, towards the end of the process, the ashes and remaining coal became coated and glazed with saline matter, which appeared to be soda, partly in the state of phosphate; and it is not a little remarkable, that the 11,25 grains obtained from albumen, consisted principally of soda, in a caustic state, (by reason of the long continued heat,) mixed with a small quantity of phosphate of soda, and a very minute portion of phosphate of lime.

Pure albumen, therefore, which has not been subjected to the effects of organization, appears to contain a considerable portion of saline matter, and very little of any earthy substance; but the contrary seems to happen, in bodies which (although evidently derived from albumen) have suffered various changes by the action of the vital principle; which may be considered as the cause of organization, by which these bodies are differently modified, according to the nature of the parts of animals which, singly or conjointly, they are employed to form. In these bodies, the quantity of the saline substances appears to be diminished, while that of the earthy matter is increased, especially in the coarser kinds of muscular fibre.

Upon a comparison of the chemical properties of the substance which remains, after the separation of gelatin from the great variety of animal substances which have been so often mentioned in the course of this paper, and which need not therefore now be repeated, there can scarcely be any doubt but that it is one and the same substance, in different states of density and texture.

For the similarity of its nature was proved by,

1st. The effects of fire, and the products obtained by distillation.

2dly. Its very difficult solubility by long digestion in boiling water.

3dly. The effects produced by re-agents, on the water in which bodies like inspissated albumen or tortoise-shell had been boiled.

4thly. The effects of acids, (particularly nitric acid,) of ammoniac, and of caustic lixivium of potash.

5thly. The animal soap which was formed; and the precipitate obtained from it, by the addition of acetous or muriatic acid.* And,

6thly. The difficulty attending the putrefaction of the substance in question, when pure and dense.

The similarity in all these properties, appears to me a full proof, that it is the same substance which constitutes the principal part of membrane, sponge, horn, hair, *&c.* and even of muscular fibre.

Moreover, upon comparing the properties of this substance with those of pure albumen in a state of inspissation, so evident a resemblance in every respect is discovered, that few I believe will hesitate to pronounce albumen to be the original substance from which tortoise-shell, hair, horn, muscular fibre, *&c.* have been derived and formed.

* This appears to be a strong marked character of the albuminous substances.

There is also much reason to believe that gelatin, although it appears so different in many respects from albumen, is yet formed from it.*

It may be recollected, that in a former part of this paper mention was made, that tortoise-shell, horn, muscular fibre, and inspissated albumen, after long immersion in very dilute nitric acid, and after being well washed, were soluble in boiling water; and that a substance was formed, which (by becoming liquefied when heated, by being soluble in boiling water, by being precipitated by the tanning principle and by nitro-muriate of tin, and lastly, by forming a gelatinous mass when the aqueous solution

* In addition to the chemical properties by which gelatin and albumen are distinguished, particularly the different effects observed when these two substances were treated with nitric acid, I shall mention some others, not less remarkable, which are produced by the muriatic acid.

When any of the varieties of gelatin, such as glue, isinglass, *&c.* are immersed in cold muriatic acid, they are dissolved in a few hours; and the solutions thus formed suffer no apparent change, even in the course of several months. In like manner, gelatin may be separated and dissolved from bodies which contain it, such as sponge, bladder, skin, and muscle; but the part which remains undissolved, and which, with the other substances formerly mentioned, I regard as formed of albumen more or less organized, is very differently affected; for, when coagulated albumen, the undissolved part of bladder, muscular fibre, feather, quill, tortoise-shell, wool, and hair, were separately steeped in muriatic acid, they gradually became of a dark colour, and the acid was tinged with the same. The colour afforded by albumen was deep blue, inclining to purple; that of bladder was brownish purple; feather, quill, tortoise-shell, and muscular fibre, afforded a beautiful deep blue; and wool and hair, like bladder, produced a brownish purple. The change began to take place in the coagulated albumen in about eight or ten days; but wool and hair were the last which were affected. In about three months, the different liquids were become very dark, although scarcely any perceptible quantity of the immersed substances appeared to be dissolved. Nitric acid, in a small proportion, changed these blue and brownish purple liquors to deep yellow; and ammoniac, being then added, changed them to orange colour, and produced all those effects which were observed, when the nitric solutions of these substances were thus treated.

was sufficiently evaporated and cooled,) approached and resembled gelatin.

It would be perhaps too hasty to assert, that gelatin was thus absolutely formed; but, if a substance so very similar to it could be thus produced, we may with some reason conclude, that the real gelatin, with its various modifications, is formed from albumen, by the more efficacious and delicate operations of nature.

In attempting to prove that albumen or the coagulating lymph is the original animal substance, I have hitherto only stated chemical facts; but, when the phænomena attending incubation are considered; when the experiments made by eminent physiologists, such as HALLER, MAITRE JEAN, and MALPIGHI, are viewed; when the oviparous fœtus is seen to be progressively formed in and from the albumen of the egg, so that, upon the bursting of the shell which separated it from external matter, the young animal comes forth complete in all its parts; when such strong facts as these are corroborated by those afforded by chemistry, it can scarcely be doubted that albumen is the primary animal substance, from which the others are derived; and there is much cause to believe that the formation of gelatin, and of the animal fibre especially, begins with the process of sanguification in the fœtus.

As the three principal and essential component parts of the blood, *viz.* albumen, gelatin, and fibre,* appear therefore to

* The whole of the blood, which by anatomists is divided into serum, red globules, and coagulating lymph, when chemically examined, is found to consist of albumen, gelatin, and fibre. The serum which remains liquid after the coagulation of the blood, is composed of albumen, gelatin, some saline matter, and much water.

The clot or crassamentum also affords, by repeated washing, a large proportion of compose the various parts of animals, in such a manner that one (being predominant) influences the nature of that part of the animal which it is principally employed to form; and as albumen, gelatin, and fibre, by relative proportion, by the degrees of density, by the effects of organization which singly or conjointly they have experienced, by the texture of the animal substance which they, as materials and thus modified, have concurred to produce, and by the proportion of natural or inherent moisture peculiar to each part of different animals, present an immense series of complicated causes, so are the effects found to be no less numerous and diversified, by the infinite variety in texture, flexibility, elasticity, and the many other properties peculiar to the various parts which compose the bodies of animals.

albumen and gelatin; after which, a substance remains, in appearance very analogous to muscular fibre, excepting that it is in a more attenuated state. This substance (called fibrin by chemists) may be regarded as that part of the blood which has undergone the most complete animalization; and from which the muscular fibre and other organs of the body are formed.