Presented by the Widow

OF

ROBERT BENTLEY TODD, M.D.

MARCH, 1860.

RB Todd

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EXPERIMENTS
UPON THE
CIRCULATION OF THE BLOOD,
THROUGHOUT THE VASCULAR SYSTEM:
ON LANGUID CIRCULATION:
ON THE
MOTION OF THE BLOOD,
INDEPENDENT OF THE ACTION OF THE HEART:
AND ON THE
PULSATIONS OF THE ARTERIES.

By the ABBE SPALLANZANI.

WITH NOTES,
AND A
SKETCH OF THE LITERARY LIFE OF THE AUTHOR;
By J. TOURDES, M.D.
Of the University of Montpellier, and One of the Physicians
to the French Army in Italy, &c. &c.

TRANSLATED INTO ENGLISH, AND ILLUSTRATED WITH
ADDITIONAL NOTES;
By R. HALL, M.D. &c.

Contra experimentorum tenorem, somnia temere confingenda non sunt.
NEWTON'S PRINCIPIA.

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PREFACE.

NO apology, it is presumed, can be necessary, on presenting to the English public, a work from the pen of such a celebrated writer as the late Abbé Spallanzani. Few individuals have held a more distinguished place in the republic of letters, or contributed more to the advancement of science, than this illustrious author.

His experiments and observations on the vegetable and animal kingdoms; on the reproduction of the different parts of animals; his microscopical observations respecting the different systems of generation; his experiments on confined air, and on mould, which he concludes to be of a vegetable nature; his dissertations on the natural history of animals and vegetables, as well as his chemico-mineralogical productions are already well known to the learned and scientific world.

Spallanzani had previously written a small treatise on the circulation of the blood, but having multiplied and varied his researches on several different animals, and extended his views to the various phænomena of languid circulation, &c. the whole of his labours, on these important subjects were given to the world, in the present volume, a short time before his death.

It cannot be disputed, that the greatest advantages have accrued to science from the method of philosophising so happily introduced by the illustrious Bacon, and since so successfully cultivated by his followers. Reasoning from pre-conceived opinions, and arbitrary hypotheses, has now in general given place to conclusions founded on the induction of facts which are either self-evident, or ascertained by experiment: but, although, when experimental pursuits are conducted with precision and candour, reasoning by induction seems best calculated to advance scientific knowledge, and to discover principles of extensive application, yet so many are the sources of fallacy which constantly operate to produce different results, as well as false and contradictory conclusions, that too rigid an exercise

exercise of the judgment, it must be obvious, cannot be employed in our investigations and reasonings, in order to arrive at legitimate conclusions.

It is only, then, by pursuing close and attentive observation, and proceeding on the strict and severe process of experiment and induction, that we can ever hope to attain a knowledge of the general and fixed laws by which the operations of nature are governed; or, in other words, to ascertain the immutable relations which subsist between the different species of matter. It was an attentive observation of natural facts, and a close and accurate inquisition, by induction from these, which led Newton to the discovery of that law, which enabled him to explain the constitution of the universe.

Proceeding, in like manner, on the principles of inductive philosophy, the Abbé Spallanzani, rests his conclusions on the solid basis of experiment and observation; and aware of the danger of mistaking mere resemblances for identity, he never employs analogical reasoning, unless where it is the only mode of argumentation applicable to the subject. He appears uniformly to have been a faithful and an enlightened observer of nature, and to have united, with the most indefatigable industry in collecting facts, those enlarged conceptions which never fail to characterize and direct the inquiries of the man of genius. The numerous experiments instituted by him to discover the laws of the circulation, in warm and cold-blooded animals, seem to have been conducted with great accuracy, as well as the most minute attention to every circumstance that might be urged against their results, and contribute to throw light on a subject, till lately involved in considerable obscurity. His examination of these results, and his observations on the systems of other physiologists, display equal judgment and knowledge, and cannot fail to prove highly interesting to those who are engaged in similar pursuits.

Although, during the progress of the work, the translator has been occasionally led to express doubts, and to differ in sentiment from the ingenious author, neither the nature nor plan of the present publication, permitted him to notice every opinion, in which he could not fully acquiesce, or which, in his apprehension, might require farther confirmation. But whatever difference of sentiment may prevail, respecting a few of the Author's conclusions, which are, for the most part, not less supported by reason and analogy, than founded on experiment and observation, yet the facts, ascertained or confirmed in the course of these researches, are highly deserving of attention, and stand on their own distinct ground, independent of any reasoning or hypothesis whatever. *Opinionum commenta delet dies, naturæ judicia confirmat.*

The present work is enriched with notes, and a literary life of the Author, by M. Tourdes, who lived with Spallanzani, in the strictest habits of intimacy and friendship; and to whom physiologists, cannot but allow the praise of great ingenuity and learning, however they may differ with him in some of his speculations. This biographical sketch contains a well written summary of the important labours, which, for a long series of years, occupied the attention of his illustrious friend, in estimating whose merits, M. Tourdes, appears not less distinguished as a physiologist and natural philosopher, than by the candid and liberal spirit of criticism which he uniformly displays in his observations. On the whole, we need not hesitate to affirm, that the present work forms a valuable addition to physiological science, and merits the same favourable reception as the other productions of this justly celebrated Author.

R. H.

London, 25th February, 1801.

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A SKETCH

OF THE

LITERARY LIFE

OF

SPALLANZANI.

SECTION I.

LAZARUS SPALLANZANI, was born at Scandiano,* on the 12th of January, 1729. His father, John Nicholas Spallanzani, had practised as an advocate, with considerable distinction, and died regretted by his countrymen, at the age of eighty-five years. His mother, Lucia Cigliani, was a native of Colorni, in the Dutchy of Parma. Lazarus Spallanzani completed his

* Scandiano is a small town, situated north-east of the Appenines, about seven miles from Reggio, and fourteen from Modena. It contains a population of about fifteen hundred persons. The family of Vallisnieri came originally from Scandiano.

elementary studies under his father's roof.* At the age of fifteen, he was sent to Reggio, where he studied rhetoric and philosophy, under the direction of the Jesuits. The rapidity of his progress soon attracted the attention of his tutors, and likewise that of the Dominicans, both of whom thought him well qualified to sustain the glory of their order; but the pupil refused to contract any engagement with either.

From this seminary, he proceeded to the university of Bologna, where experimental philosophy was then taught by that celebrated woman, Laura Bassa. She was cousin to Spallanzani, and treated him with all the regard of an affectionate relative, a sincere friend, and an enlightened tutoress. The pupil was not ungrateful, and he soon justified the warm expectations which had been entertained of him. A splendid thesis, which he maintained amidst the

* I might add a number of common-place remarks respecting the infancy of Spallanzani, his propensities, amusements, &c. but the sagacity and penetration of early life do not always prognosticate an enlightened judgment, and a lively imagination in manhood. I have been assured, however, that so remarkable was the acuteness of young Spallanzani, that his companions gave him the name of *the Astrologer.*

applauses of a numerous audience, soon raised him above his class-fellows: the professors of that celebrated school admitted him into their society; and some of them, even employed him to fill the chair in their absence.

During this period, Spallanzani studied the Greek and French languages, under Doctor Bianconi. The former was the object of his more particular attention; and he was soon capable of reading Homer and Demosthenes with ease. Convinced of the justice of Horace's precept,

——— "Exemplaria Græca
"Nocturna versate manu, versate diurna,"

every moment that he could spare, was occupied in perusing those immortal productions; and to them, doubtless, are to be attributed that perspicuity, energy, and eloquence, which characterize his own compositions.

In compliance with that custom which destines children to adopt the profession of their fathers, Spallanzani applied himself to the study of jurisprudence. But the dryness of that study, was little calculated to captivate a mind lofty, independent, and already susceptible of the boldest conceptions. Accordingly, after a few years of labour and disgust, he resolved to abandon a profession for which he felt himself neither inclined nor adapted, and resumed his physical and mathematical studies, which he pursued, for three years, with all that ardour which is usually excited by the recollection of difficulties already overcome, and the view of fresh obstacles to be surmounted. Hence were derived that talent for analysis, that acuteness of observation, which were to conduct him to the most splendid discoveries; that sound logic, which admitting only the clearest premises, and the strictest conclusions, guarded him against the fallacies of hypothesis, and the illusions of self-love, and the imagination.

By this time, his reputation began to fill a larger sphere; his correspondence was every where courted; and the school, in which he had learnt the first elements of science, eagerly appointed him to teach philosopy and the *belles lettres*. Spallanzani was only twenty-six years of age, when he was elected Professor at Reggio, where he laid the foundation of the majestic edifice of his glory. That city can boast of being the first which enjoyed the presence of a philosopher, who must be ranked amidst the greatest

greatest of those that have done honour to the Italian name.

We shall now proceed to trace the different epochs of his literary life. By turns a chemist, an experimental philosopher, a physiologist, a naturalist, and a man of literature, we shall find him in every character a profound genius, an able observer, a close reasoner, an eloquent writer, and an accomplished author.

§ II.

Salvini's translation of Homer has been regarded as one of the best that has ever been published*. It is, upon the whole, executed with fidelity and care; but on examining it with some attention, it will be found, that the translator may be accused of a variety of errors, mis-interpretations, and omissions.

* At present, we very justly prefer the translation by the Abbe Cesarotti, professor of eloquence, and the *belles lettres*, in the university of Pavia. In the "*Notices litteraries sur l'Italie*," may be found some account of the other writings of this poet, who is but too little known in France.

Spallanzani, amidst the shady groves of the delightful villa of Montfalcon, and remote from all philosophical speculations, traced, for the perusal of Count Algarotti, the result of his observations upon Homer, and frankly pointed out to him faults of the grossest description, which have been committed by the Florentine translator*. According to his opinion, Salvini enfeebles the energy of the Greek language, by too exuberant a diction; occasionally misrepresents the sentiment, making the poet say what he never meant; and totally misconceives the sense and signification of a very great number of expressions. Spallanzani justifies these several charges. He enters into the most curious details respecting the etymology of a variety of words, ascertaining their real import, and restoring the true sense of the Greek text; and he discovers in his native language expressions sufficiently bold and energetic, to copy the splendid and glowing imagery of Homer, which is obscured or dis-

* Lettere tre dell'Ab. Lazzarro Spallanzani, al sig. Comte Algarotti, Reggio, 1st June, 1761. These letters are inserted in the 14th vol. of the new edition of Algarotti's works, printed at Venice, in 8vo. They have never, so far as I know, been published in any other shape.

figured by the Italian Poet. He notices, in a more particular manner, the famous description of that divine and mysterious cestus which Venus presented to the queen of the gods; a description which the poets of all nations* have attempted to

* The reader, perhaps, will be gratified by my subjoining to the translation criticised by Spallanzani, that of Pope and Cesarotti, and the imitation by Dumoustier.

And from her fragrant breast the zone, unbrac'd,
With various skill and high embroid'ry grac'd.
In this was ev'ry art, and ev'ry charm,
To win the wisest, and the coldest warm:
Fond love, the gentle vow, the gay desire,
The kind deceit, the still-reviving fire,
Persuasive speech, and more persuasive sighs,
Silence that spoke, and eloquence of eyes.

POPE's *Homer's Iliad, book* xiv.

, ... E si dicendo,
Scioglie dal petto alabastrino il cinto,
Cinto d' inenarrabile textura,
Di portenti fecondo, alle sue fila
Invisibili al guardo, erano intorno
Quei susurranti pechie à fiori estivi,
Tutti i genj d' amore, i cari vezzi,,
Gli accorti cenni, il tenero sorriso
E desio tutto foco, e la repulsa
Dolse ritrosa che negando invita,
E silenzo che chiede, e il bel mistero
Col dito in su le labbra, e la soave

 Sospirosetta

to translate, or to imitate, and of which Salvini has doubtless succeeded in giving a version worthy of our highest praise. It is as follows:

Sospirosetta, amabile tristezza,
E i vaghi sdegni, e le animate paci,
E i molli scherzi, e volutte spiranti,
Ebrezza di delizie, il quanto al fine
Forma il senso ineffabile per cui
Delira il saggio e s 'incantena il forte.

Book XIV. p. 48, vol. 2, Turin edition.

On y voyait l'Amour conduit par l'Espérance,
Les timides Aveux, la molle Résistance,
La Pudeur enfantine et les jeunes Plaisirs
Qui fuyaient, agaçaient, caressaient les Desirs,
Aupres d'eux paraissaient la Volupté, ses charmes,
Ses transports, sa langueur, les yeux baignés de larmes,
La douce intimité, les soupirs, les sermens,
Les caprices suivis des raccommodemens.

But on the reverse of the cestus.

La main des tristes Eumênides
Avait tracé les noirs soupçons,
La haine, les baisers perfides,
Les vengeances, les trahisons,
Par de sombres détours la pale Jalousie
Se traînant d'un pas chancelant,
A l'Amour infidéle arrachait en tremblant
Le masque de l'Hypocrisie

Letters on Mythology, part 2. page 38.

"Disse;

> "Disse; e del petto sciolse da belta punto
> Cuojo, ingegnoso floviato e vago;
> Ov' lavorati son tutti i suoi vezzi,
> E l' attrative tutte e leggiadre;
> Ove é l' amore, il genio, il favello,
> La Consolazione colla Carezza.
> Che ruba il senno ai savj ancor più grandi."

May we not, however, be permitted to ask, whether it be not inferior to the version of Boileau, and whether Jupiter would not have preferred to see the immortal goddess in her French garb.

> "Après ces mots Venus detacha sa ceinture,
> Ouvrage industrieux, rare et belle parure.
> Où brillaient à l'envi les plus charmans attraits,
> L'amour, les doux desirs, les entretiens secrets,
> Les discours décevans, le doux et feint langage,
> Qui derobe souvent le cœur même au plus sage."

It would be superfluous to follow Spallanzani any farther, at present, in his judicious critique upon Salvini's translation of Homer. In criticising that performance, he does not assume the tone of the haughty rhetorician, or the pedantic grammarian. The most varied erudition is, in every page of it, accompanied with the most correct judgment. He exhibits, through-

out

out the whole, a profound knowledge of the Greek language; and, while in some parts, he indulges in all the ingenious subtleties of criticism, in others he collates and compares, in a manner at once interesting and acute, different passages of the Iliad, as they have been imitated, translated, or commented upon, by the bard of Mantua, the poet of Arezzo, and the author of the 'Art of Poetry.'

§ III.

The origin of fountains is certainly one of the most wonderful arcana of nature. If the sight of water bursting from a rock, or rising in the midst of a plain, does not strike us with astonishment, it is because we have been always accustomed to see it, and because familiarity stamps a mark of indifference on objects the most entitled to our admiration.

The primitive origin of fountains, however, has long been a subject of disputation. The antients had recourse to a mysterious cause. A plaintive Naid was supposed to shed, amidst the recesses of the forests, a torrent of tears, which refreshed the parched ground, fertilized the meadows, and flowed along in a timid rivulet, or a

raging

raging current. On the other hand, some of the moderns have supposed that the waters of the sea circulate in the bowels of the earth, and that springs are so many canals or syphons by which they find their way to its surface. But this opinion, founded on a particular religious creed, and strongly supported by the enthusiastic sect of Cartesians, vanished before the cool reasoning of the philosophers of the last century. The general opinion of the present age is, that the vapours which are incessantly exhaled from the surface of the earth, being condensed in the higher regions of the atmosphere, fall upon the summits of the mountains, filtrate through the minute crevices, and on meeting with substances which oppose their further descent, escape to the surface through the fissures which afford the easiest declivities, and thus become the origin and source of fountains.

Spallanzani, in his occasional excursions to the Appenine mountains*, had the satisfaction of, in some measure, surprising nature in the primitive formation of fountains. He observed that

* Descrizione d'un viaggo montano, con osservazioni sull' origine delle fontane, lettere due al Vallisnieri figlio 1762—Racolta d'opusculi scientifici, tom XIV.

they

they were more or less numerous and abundant, according to the direction of the mountains, their structure, and, particularly the facility which they presented of converting the suspended vapours into water, and their disposition to collect and transmit it through the lateral orifices, which were invariably below the level of the tops of the nearest or adjacent mountains.

Is the rebounding of a stone, when flung obliquely upon the surface of a lake or river, to be attributed to the elasticity of the water? This is the opinion which generally prevails; but Spallanzani, from the result of a very ingenious process, of reasoning and calculation*, ascribes the effect to a necessary change in its line of direction, produced by the cavity which it forms on touching the water; and he accounts for the repetition of the rebounds, as long as the original projectile force continues, from the smallness of the angle, of projection, which is occasioned by each successive cavity.

*De lapidibus ab aqua resilientibus dissertatio, 12mo, 1766.

This dissertation, which was dedicated to Laura Bâssa, may likewise be found in the collection mentioned in the preceding note.

Spallanzani

§ IV.

Spallanzani held his professorship in the College of Reggio, for six years. It was in that city that he formed the first presentiment of the celebrity which he should, one day, attain as a Naturalist. The microscope was the instrument of his first experiments, which were employed in elucidating the history of the *animalcula infusoria**, and at once, displayed a mind observing, acute, correct, and capable of the most sublime researches. His fame was soon wafted across the Alps; and his name was mentioned with honour on the banks of the Po, the Thames, the Tagus, and the Volga. Different universities, both at home and abroad, courted the presence of a man, who commenced his literary career under such brilliant auspices. Those of Coimbre, Parma, Ce-

* Though Spallanzani did not publish his first Essay on the Animalcules of infusion, until after his removal to Pavia, it appears from a letter of Needham's to Charles Bonnet, that he had prepared the materials for it, before he left Reggio. I make this remark, because several authors have attempted to ascribe to themselves a number of discoveries which Spallanzani had communicated in his lectures at Reggio, long before their works were published.

sena,

sena, Modena, and Petersburgh, made him offers of the most honourable and advantageous nature. He gave a preference to Modena, because he, there, had an opportunity of enjoying the intercourse of his relations. He was, at this time, in the thirty-third year of his age.

§ V.

Vegetables re-produce their stems, which shoot forth, encrease, and bear blossoms, leaves, and fruit. Is an animal, in like manner, endowed with the power of regenerating the organs of which it may have been deprived? Do the new organs present the same structure with those which they succeed? and are they capable of performing the same functions? This is, doubtless, one of the most interesting subjects of enquiry within the province of natural history; and it has, accordingly, attracted the attention of several physiologists. Yet, from the want of a sufficient number of observations and experiments, the theory of animal reproductions was still in a very obscure state. Some denied the existence of a regenerative power, or admitted only the reproduction of inorganic parts, produced by the passive operation of extravasated matter, without any regular and definite structure; and others

others alleged, that the example of a few animals of the most simple organization, was not sufficient to resolve a problem of a nature so complicated and extensive.

It must, indeed, be admitted, that the regeneration of the Polypus, and a few small insects, cannot establish a general and common law with respect to all animals; but if such as are furnished with nerves, fibres, blood-vessels, a heart, stomach, and brain, are found to possess the faculty of reproducing different organs, we must abandon ourselves to the most ridiculous scepticism, or give our assent to a regenerative power, whatever questions may arise as to its mode, its essence, and its means. No one has treated the subject of animal reproductions in a manner so varied and original as professor Spallanzani*.

* *Prodromo sopra le riproduzioni animali*, in 8vo. Modena, 1768. This little piece, which has been translated into English, French, and German, is nothing more than an outline of a large work which Spallanzani intended to give the world, upon animal reproductions. But though he repeatedly signified this intention, the work never was published. I one day asked the reason of this delay; he replied, that the details and elucidations given by his friend Bonnet had superseded the utility of his work.

He

He confirmed the multiplied regeneration of the polypus and the common earth-worm; and discovered that the fresh-water worm reproduces itself *ad infinitum;* each part, into however many it may be divided, becoming a complete animal of its species. Several animals of a superior mechanism afforded results no less surprizing. Toads, of different kinds, recovered their paws, lizards their tails, the water snail its horns, and the land snail almost all its members. Our author had even asserted that the latter reproduced its head; but later and more correct researches have shown that the brain of the land-snail is not situated in the part which was amputated. The experiment, however, is not the less wonderful. If it does not prove the renovation of a head, it presents, at least, the regeneration of a member furnished with a very complicated organic apparatus*.

Every

* Spallanzani strongly maintained the reproduction of the head of land-snails. In a well-written paper, inserted in the translations of the Italian Academy of Verona—*Resultati di sperienze sopra la riproduzioni della testa nelle lumache terrestri.* Vol. I. 1782 and vol. II. 1784. He re-considers his experiment on the subject, and adds several new facts and details. He quotes, likewise, at considerable length, those writers who supported or contradicted

Every one must have heard of the wonderful powers which are attributed to the Salamander. A subtle, but mortal, poison was supposed to flow in its veins, and it could live and multiply in the midst of the flames, which were regarded as its natural element. Sound philosophy has banished all these chimeras, and demonstrated the falsehood of so many supposed properties.

Though despoiled, however, of its imaginary prerogatives, the Salamander is still an object worthy of our admiration. Not only does it renovate its jaws, tail, legs, &c. but it even recovers all these members, after repeated amputations, so that, cutting off its extremities in succession, it will be found, that, in the space of two months, no less than ninety-nine bones have been completely re-produced.

contradicted his opinion. Among the former the most distinguished were Turgot, Lavoisier, Tenon, Herissant, Bonnet, Senebier, Scheffeer, Muller Roos, and Troile; among the latter, Murray, Wastel, Cotte, Bomare, Adanson, Schroeter, Argenville, and Presciani. The latter shewed that Spallanzani had amputated a part very different from the brain. I have seen the anatomical preparation from which he drew up his paper: it is deposited in the physiological cabinet of the university of Pavia, which, in a great measure, owed its formation to the talents and interest of this celebrated physiologist.

§ VI.

The astonishment excited by his researches, relative to animal re-productions, had not yet subsided, when Spallanzani published a small tract on the circulation of the blood*. This performance was dedicated to Haller, as the fruit of a studious perusal of his immortal productions relative to that important function.

The Salamanders became the victims of his relentless curiosity. Spallanzani first drew them from the happy obscurity they had, hitherto, enjoyed, and communicated to them a share of the celebrity, which seemed exclusively appropriated to the Frogs. The Salamanders have a great number of vessels; they are very transparent; and it is easy to prepare them, and to observe the phenomena which they exhibit.

The principal object of the professor's researches, was to ascertain the action of the heart upon the arteries and veins, and the relative ve-

* *Dell' azione del cruore ne' vasi sanguigni, nuove osservazioni dell' Abatte Spallanzani, Prof. di Filosofia, nell' Universita di Modena*, &c. in 8vo. 1768.

locity

locity of the blood in the larger, middle-sized, and small vessels. His observations are not always in unison with the general opinion: some of them entirely overturn several of the facts advanced by the physiologist of Berne. How many are there who would have severely retaliated for this contradiction? so tremendous, sometimes, is the indignation of Philosophers! But Spallanzani had taken an oath of allegiance to Nature and to Truth; and, besides, his opponent was one of the mildest, kindest, least envious, and best informed of mankind:—this opponent was Haller.

§ VII.

The art of making experiments, consists not in merely collecting, arranging, and classifying facts. It is, previously, necessary to conceive the processes which are to determine the success of the experiments, and to ascertain the path by which nature is most accessible. Above all, this art requires an ardent love of truth, the abandonment of the most favourite opinions, a mind unshackled by systems or prejudices, and an understanding capable of the most cool and rigorous reasoning; otherwise, it becomes a teeming source of errors, which are the more dangerous, as they are so well calculated to gain belief, and so very difficult of refutation. Spallanzani was not deficient in any of the qualifications requisite for discovering the secrets of nature, by means of the art of experiment; but he possessed an imagination so active and fertile, that it was impossible for him to execute all the projects which it suggested. Many of them, he merely noted in his journal, in the expectation that they might be fortunately realized at a future opportunity. It was, doubtless, as much from his own want of leisure, as from a zeal for the advancement of natural history, that he was induced to publish a series of experiments to be made on the generation of mules in the class of insects*. But I have not yet heard of any one attempting to profit by this simple and well digested plan; though it would, certainly, throw some light upon one of those functions with which we are least acquainted, the fecundation of animated beings.

§ VIII.

Spallanzani, for some time before this period, carried on a regular correspondence with

* *Invito a intra prendere sperienze onde a vere muletti nel popolo degli insetti per tentar di sciogliere il gran' problema della generazione*, in 8vo. Modena, 1768.

Charles

Charles Bonnet. They mutually communicated to each other their labours and discoveries; and neither of them published any thing without previously consulting the other. It would be difficult to select, in the whole course of epistolary history, two philosophers who maintained, on both sides, a more intimate, active, and unreserved intercourse. It was as much, perhaps, from a principle of gratitude as of friendship, that the professor of Modena translated into Italian the celebrated contemplations of the naturalist of Geneva*; and the number of valuable notes with which he enriched it, have contributed not a little to the sale of the work. It has, already, gone through fifteen editions.

§ IX.

The University of Pavia†, towards the middle of this century, presented nothing but the

* *Contemplazioni della natura del Signor Bonnet trad. dal Francese con note.* Modena 1769. 2 vols. in 8vo.

† Pavia, anciently a Roman municipal city, was the residence of several emperors, and of almost all the kings of the Lombards. Pillaged and sacked, every time its

remembrance of the celebrated men who had once been its professors. It had neither library, experimental apparatus, museum, cabinet of anatomy,

territory became the theatre of war, it now presents only the dismal remains of a once flourishing city; houses in ruins, streets deserted, ramparts demolished, tottering towers, a scanty population, and an atmosphere loaded with mephitic exhalations. Every thing in this city is a source of melancholy reflection to the feeling traveller. It is the inhabitant only who beholds its ruins with indifference; the past grandeur of his country excites no interest in his mind; it is effaced from his remembrance. He sees only its present misfortunes, without making an effort to repair them, or to prevent the arrival of still greater calamities. He drags out a monotonous life of indolence; and the only thing of which he boasts is the university, which is, beyond doubt, the most renowned in Italy. Yet the Ticino washes the walls of Pavia; it is navigable as far as the mountains of Switzerland; it falls into the Po, at two or three miles distance from the city; and the Po flows through the whole course of Lombardy, from the French Alps to the Adriatic sea. There are few cities in the interior of Italy so commodiously situated for the establishment of manufactures and central warehouses. But it must be admitted, that the concurrence of more fortunate circumstances, some encouragement from the government, and particularly a little more activity and industry on the part of the good people who inhabit it, will be necessary to the accomplishment anatomy, nor botanic garden. Every branch of learning was reduced to the most deplorable languor. History will record the efforts made by a philosophical queen*, to restore that illustrious school to its former splendor†. Under her patronage,

ment of these objects. Let them begin, in the first place, with draining their marshes, those sinks of corruption and death; and this they can effect the more easily, as it will require but very little time and expence to make cuts from them to the rapid streams in the vicinity. The annual mortality at Pavia is one in twenty-seven; or more correctly speaking, the number of those who die in one year is to that of the survivor as 1 to 27 $\frac{1714}{4065}$. The mortality at Mantua is still greater; for there it is as 1 to 19 $\frac{3845}{48}$. At Milan the proportion between the dead and living is as 1 to 31. See an excellent memoir by Fontana, entitled,—" *Dissertazione di aritmetica politica, soprà il modo di calcolare la vita media dell' uomo e soprà l'errore degli scrittori d'aritmetica politica, e di qualche geometra di confondere la vita media colla vita futura probabile.*" Milan, 1798, in 12mo.

NOTICES LITTERAIRES SUR L'ITALIE.

* The Empress, Maria Theresa.

† Among the professors who have done most honour to the old school of Pavia, is Gaspard Aselli, who taught anatomy there towards the beginning of the sixteenth century. He discovered the lacteal veins, which form one of the principal divisions of the lymphatic system.

tronage, the University of Pavia had soon to boast of including among its professors, men of the most distinguished attainments, in physics, mathematics, medicine, &c. a Boscovich, Gregory, Fontana, Burserius, and Moscati. Spallanzani was invited to it, in the year 1770, to give lectures in Natural History. A few years before, he refused a similar situation, which became vacant in the University of Padua, by the death of the younger Vallisnieri.

Here commences the most splendid period of the life of Spallanzani. Appearing on one of the most conspicuous stages, we shall behold him acting a distinguished part among the most celebrated performers, and even soon surpassing his illustrious competitors.

Having engaged to teach a science which he had studied without a master, and only as he

tem. At the time when he was employed in describing them, he little thought that the finest preparations of these vessels would one day be made in the same place. The drawings which decorate his work, can now serve only to shew the progress of the art of anatomical design; and in this way, it is curious to compare them with the plates given by the immortal professor of Sienna.

NOT. LITT. SUR L'ITALIE.

found

found himself disposed to it at his moments of leisure, it is curious to enquire what model he had selected for the guidance of his lectures and researches. This question is sufficiently answered by himself, in the eloquent discourse which he pronounced on the day of his inauguration.

"Cumulatissima sunt promerita utrique gallo (Réaumur et Buffon) communia; sed unius opiniones et cogitata severiore alterius temperantur judicio. Ambo, si ingenii fertilitatem consideres, eò amplitudinis et excellentiæ pervenerunt, ut in florentissimo hoc sæculo, in tantâ naturæ investigatorum ubertate vix aliquos habeant pares, superiorem certe neminem. Ambo in eâ naturalis scientiæ provinciâ, quam pertractandam aggressi sunt, omnium expectationem vicerunt, ille quidem animalium minorum, hic grandiorum regnum æternitati commendans. Ambo veluti è cœlo delapsi, rebus pridem involutis, perturbatis, difficillibus perspicuitatem indiderunt, ordinem, facilitatem. Sed observandi artificiis instructior Reaumurius, sigillatim phœnomena perlustratur, lente expedit, prudenter comparat, aliaque ex aliis colligens, abditas rerum causas, nec ita infrequenter, felicissime evolvit. Vividiore Buffonius imaginandi vi præditus, rerum perscrutandarum

perscrutandarum non patiens in promptu posita tantum persequitur, obstrusiora vero tanquam delphino oraculo instructus divinando concludit. Ille nihil sibi tribuens, phœnomena, ut a naturâ repræsentantur, videt. Hic, genio suo indulgens, plus semel phantasiæ depincta coloribus contuetur. Oratione ille utitur simplici, lætâ nec inelegante, in eo tamen nonnihil fortasse peccante ut singula feret minutiùs; hic magnificâ, supra fidem disertâ, eo sententiarum pondere ornatâ iis verborum luminibus illustratâ, tot tantisque alliciendi suadendique leociniis communicatâ, ut oratorum hujus memoriæ facile princeps habeatur et sit*."

His choice was not long doubtful; it fell on the author of the History of Insects. Spallanzani was, perhaps, ambitious of imitating both. But does he equal the French Pliny in grandeur of ideas, sublimity of conception, majesty of style, richness of colouring, and those bold and vigorous touches which, at once, astonish and captivate? and will not Reaumur, from the multiplicity of his researches, the variety of his materials, and the simplicity of his processes, be always regarded as the chief of experimental philosophers?

* Prolusio Lazzari Spallanzani, in reg. gymnasio ticinensi. In 8vo, page 21.

§ X. In

§ X.

In the whole course of the annals of medicine, there is nothing which more excites our astonishment, than the unequal progress which its different branches have made among the ancients and moderns. The practice of the healing art is still, with a very few exceptions, the same with that of the venerable physician of Cos. We adopt his principles, pursue the same track, incessantly revert to his works; and, scarcely, in a single point of importance, have we improved his clinical system. But how great the difference with regard to the science of the animal economy! Ignorance of causes, superstitious principles, nugatory facts, vague details, extravagant hypotheses respecting the action, and even the functions of a great number of the viscera; every thing, in short, contributed to disfigure the physiology of the ancients. We, on the other hand, have discovered the circulation of the blood, the properties of the fibres, the laws of sensibility, the mechanism of the senses, the distribution of the lymphatic vessels, the mode of digestion, the cause of animal heat, the composition of the humours; in a word, we have removed a part of the veil which covered the process of generation, and almost resolved the grand

grand problem of nutrition. Whence proceeds this striking contrast in the progress of the medical sciences, between the ancients and the moderns? May we not justly attribute it to their different method of studying nature? The former confined themselves entirely to observation, the surest means of acquiring a knowledge of diseases; the latter are principally guided by experiment, on which is partly founded the doctrine of the functions of the living system. Observation puts us in possession of those sensible effects and phenomena which discover themselves in a spontaneous manner: it is the mirror in which the rays reflected from the surface of objects are concentred in a focus. Experiment, on the contrary, explores the interior of bodies, and, disregarding their superficial appearances, penetrates their most hidden recesses. The one studies the laws, the relation, and the action of elementary principles; the other investigates their nature and composition. Tranquil and calm, that attentively watches; more active and adventurous, this agitates, discomposes, and destroys. Simple, and unbiassed by any particular object, observation faithfully records every thing that appears, the most simple, as well as the most complicated facts. Haughty and systematic, experiment often turns her attention

tion to facts only of the most singular kind, and collects those only which accord with a theory already conceived and determined. Observation, without experiment, left the ancients in the dark, as to real causes; experiment, without observation, too frequently prevents the moderns from attaining a complete knowledge of facts, their order, and mutual dependence. But both of them fortunately conjoined, were the guides whom Spallanzani followed in a multiplicity of important researches, among which, those that relate to the circulation of the blood, hold the most distinguished place.

It is well known that the author of this discovery did not enjoy the satisfaction of seeing, with his own eyes, the circulation of the blood. It was reserved for Malpighi to be the first to enjoy this magnificent sight, and for Spallanzani, next after Haller, to discover some of the most curious laws respecting the motion of the blood, its causes and effects*.

His work upon this subject being but little known in France, it may not be uninteresting

* *De' fenomeni della circolazione osservata nel giro Universale de' Vasi*, &c Modena 1777, in 8vo.

to

to state here the result of a few of the experiments which it details.

1. The heart does not entirely empty itself in the systole—Haller thought otherwise. He conceived that if any portion of the blood remained in the cavities of the heart, it would, by a continued excitement, oppose the state of diastole; but Felix Fontana* has justly observed that the blood which then remains in the ventricles, cannot preserve in activity the contractile force which they possess.

2. Does the blood flow with an uniform velocity from the heart to the most distant extremities of the arterial branches?—On considering the nature of this fluid, the canals through which it flows, their flexures, angles, unequal diameters, &c. we might, at first, be induced to conclude that the velocity of the blood must decrease in proportion to its distance from the heart; this, at least, is the consequence which would result from a strict application of the

* Ricerche Filosofiche, &c. a work in which the author has ably explained the laws of Hallerian irritability, the existence and phenomena of which may be easily reconciled with the happy discoveries of Galvani and Volta.

laws of Hydraulics to the animal economy. Haller suspected that this application was false; and he founded his opinion principally on the almost equal velocity observable in the largest arteries and the smallest veins. If it be true that the motion in the latter is equally rapid as in the large arterial trunks, we cannot but suppose, that the velocity is not diminished in arteries of the same diameter with the smallest veins. This, however, was but mere conjecture, until the experiments of our author converted it into a reality.—He found that the blood invariably circulates with equal rapidity in the large and middle-sized vessels; that it loses nothing of this rapidity in the very smallest; and that the angles and curvatures, whether natural or artificial, neither augment nor diminish its momentum. The circulation, however, is not entirely uniform throughout the whole of its course; close to the heart the blood experiences an alternation of motion and rest, corresponding to the systole and diastole of that organ. In proportion as it recedes from the heart, this alternate change disappears; the blood flows more rapidly during the systole; and it proceeds with the same degree of velocity to the very extremities of the arteries. These three gradations are not very perceptible,

perceptible, except when the circulation is not disturbed by any extraneous cause.

3. The arteries are transformed into veins in various ways. Some of them, in becoming veins, bend back their course immediately towards the heart; others, previously, form a thousand doublings and windings. While one anastomoses directly with a vein; another communicates with it only through an intermediate tissue. Here an artery branches into a variety of veins; and there a number of arteries unite in a single vein. The number of globules which pass from an artery into a vein, corresponds in general to the capacity of the canal.

4. It was farther supposed, though more from theoretic reasoning than observation, that the venous blood accelerates its motion as it approaches the heart. Haller could easily observe that the blood circulated in the trunk of a vein with greater rapidity than in the branches which open into it. But a single fact was not sufficient to establish a general law.—Spallanzani made a great number of experiments upon this subject. On a careful examination of several veins throughout the whole of their course, he perceived that the circulation increases in proportion

tion as the venous vessels enlarge their diameters, admit a greater quantity of blood, and more nearly approach the heart. The result of his enquiries into the ratio of this velocity, was that in the large vessels it scarcely exceeds by one third that of the smallest.

5. When two veins of unequal diameters anastomose with each other, the current of the larger strongly opposes the influx of the blood from the smaller. Nature, accordingly, seldom forms a communication between veins of a very disproportionate size; the small ramifications which tend towards the same trunk, previously receive auxiliary branches which augment their diameter, so as to render it gradually equal to that of the trunk, and, thus, to remove every obstacle to the passage of the blood.—Such was the theory of Haller. But this theory is contradicted by the experiments of Spallanzani, who asserts that the blood passes without impediment or delay, from the smallest into the largest veins, whatever be the angle which the branch forms with the trunk. The same phenomenon is observable in almost all the vessels, and the law of Haller is, at most, nothing more than an exception.

6. Does the momentum of the blood depend entirely on the action of the heart? Such was the Professor's opinion, of the truth of which he was so firmly convinced himself, that he conceived he should convert the most incredulous of his readers.—It is certainly a matter of surprize that he, who had so often seen the blood circulate, with rapidity and regularity, in vessels separated from the heart by ligature or division; who had ascertained the existence of a distinct action in the arteries and veins; who attacked with so much force of reasoning, the too general theory of Harvey; and who combated, by the most direct arguments, the doctrines of the *Mechanicians*—should, yet, have adopted an opinion so favourable to their hypothesis, so contrary to the result of his own experiments, and even so opposite to the title of one of his dissertations—"*The motion of the blood, independent of the action of the heart.*"

7. The veins are more numerous than the arteries; they are larger in diameter, and the impulse of the heart operates upon them, only in an indirect manner. Yet, Spallanzani assures us, that the blood circulates with the same velocity in the veins and arteries, whatever be their diameter, length, and distance from the heart. It

It is, however, necessary, he observes, that our estimate be made from the correspondent arteries and veins; for, if we compare those which belong to different organs, we shall find a considerable variation in the course of the blood; thus it flows more rapidly in the pulmonary vessels, than in those of the mesentery, &c.

8. Haller is the only physiologist who has collected the various phenomena of languid circulation; that is, when it is on the point of entirely ceasing. From being, at first, strong and rapid, according to his account, it suddenly diminishes its velocity, becomes irregular, makes a retrograde movement, osillates, and finally stops altogether;—Spallanzani, however, asserts, that all these irregularities proceed from the mode of experiment adopted by Haller; that the blood is sensibly diminished in velocity, at the commencement, then abates its current by little and little, and, at last, becomes stationary in a gradual and insensible manner, without ever exhibiting, in a natural state, any oscillation, or retrograde movement*.

9. On

* I regard this pathological phenomenon, namely the retrograde, oscillatory, or intermittent motion of the blood,

9. On opening an artery, or a vein, the blood contained in it instantly forms a double current, which directs itself towards the orifice. The upper current makes a retrograde movement, the lower one ascends; and both, redoubling their velocity, escape through the opening that has been made. This discovery, for which we are indebted to Bellini, was varied by the Professor, in a thousand ways, by experiments on vessels of different sizes, of unequal velocity, and more or less distant from the heart. In all these the result was uniformly the same. What is the cause of this accelerated motion and double current? Haller, at first, attributed them to the attraction of the globules; but, on more mature consideration, he admitted an invisible contraction in the coats of the vessels, which is, at present, the most general received opinion. It does not, however, agree with the researches of Spallanzani; but these are not sufficiently conclusive to effect its complete refutation.

blood, as an effort of nature struggling against the obstacles which impede the exercise of her functions. If means were employed to produce and regulate this motion in certain chronic disorders, would they not be infinitely more efficacious and salutary than the great variety of pretended alterative medicines now in use.

10. Has

10. Has the gravity of the blood any influence on its circulation? Does it accelerate the circulation by acting from above downwards, or retard it by acting in a contrary direction? The gravity of the blood has a manifest influence on the large and middle sized vessels. When it operates in the direction of the blood, it augments its velocity; but diminishes it, on acting in the opposite way. The small vessels only are excluded from this law.

11. The original colour of the blood is red. The yellow and whitish shades, which it sometimes exhibits, are merely optical illusions produced by an imperfect light.

12. The globules of the blood float in an invisible and elastic* fluid. Their figure is nearly

* Spallanzani's experiments render very probable the existence of this fluid, or elastic and invisible gas, and the additional facts which I have stated in one of my notes, completely establish it. The nature of this gas is still unknown; it were much to be wished that some chemist would analyze it. A knowledge of its constituent principles would, I am apt to think, throw very considerable light on some facts respecting respiration and sanguification, which are still involved in obscurity. This gas appears

spherical, and they are elongated or compressed, according to the diameter of the vessel through which they pass.

13. Warm-blooded animals have, in the early stage of life, a much greater quantity of globules, than the cold-blooded animals. But as the latter grow in size, the number of globules encreases; so that, after a certain time, it is as considerable, *cæteris paribus*, in the one as in the other class. —The vessels of a cold-blooded animal are always sufficiently transparent to permit the motion of the blood to be seen through them; whereas those of a warm-blooded animal are furnished with coats so thick, and so little transparent, that it is impossible to enjoy this spectacle but for a few days after birth.

14. Cold-blooded animals survive some days, after the destruction of the heart and brain;

to me to be the cause of a great number of the phenomena peculiar to the blood. Ought we not to abate somewhat from the progressive or circulating motion of this fluid, and consequently from the general laws which have been thence deduced, and take into account the expansion and rarefaction of the gas confined in the veins and arteries? I refer the reader, upon this subject, to the able enquiries of one of the best informed men in Italy, the Chevalier Rosa, professor of medicine at Modena.

they

they die sooner, however, when deprived of the former organ *.

Spallanzani

* 1. It is a very great error to suppose that the power of animal sensibility is confined to the brain and spinal marrow. These parts, undoubtedly, form the central point of the nervous system; but it would be as absurd to regard them as the only seat of its functions, as it would be to place the circulation exclusively in the heart, digestion in the stomach, &c. &c. Besides, it is sufficiently proved by the experiments of Galvani, and particularly by those of the Newton of Electricity, Alexander Volta, that the nerves, when separated from the brain, retain the power of exercising the same functions as in their entire state.

2. It is likewise an error, and one of which the effects have been very detrimental to the progress of physiology, to attribute to the nerves all the phenomena of vitality. The nervous system is, certainly, that which most deserves to be distinguished by the denomination of the vital system; that which possesses an action in some measure more independent, and, at the same time, more generally connected with the different viscera, than any other part of the animal economy; that even which communicates to, and receives from them, the most powerful impressions; but still it is very far from being the universal proto-type of life, the absolute organ of animality.

3. I am pretty strongly disposed to think that the sanguiferous system possesses the power of vitality, in a de-

Spallanzani did not confine his experiments to one species of animals. On the contrary, he extended

gree very little inferior to the nerves.—I. Lesions of the heart produce consequences equally fatal as those of the brain. Animals die sooner after the destruction of the first organ, than on being deprived of the second.—II. The compression or division of a vein, and especially of an artery, produce the same effects as those of a nerve; viz. palsy, atrophy, &c.—III. The injecting of a fluid into a blood vessel, or rather its commixture with the blood, occasions *subsultus tendinum*, convulsions, in a word, a variety of phenomena similar to those produced by the pricking of a nerve.—IV. The properties of vigour, strength, and health, are in proportion to the evolution of the sanguiferous system, the concomitant of vigorous and robust constitutions, at the age of manhood.—V. The nervous power has not so great an influence on the circulation as is commonly conceived: it can, however, disturb, accelerate, or retard, the motion of the blood. But the vascular, in its turn, exercises the most powerful action on the nervous system; even inducing, in some cases, (as in a state of lethargy,) the almost total suspension of its energy. Besides, such is the influence of the heart on the brain, that its distance from, or nearness to that organ, is in some measure decisive of the sagacity and activity of animals; thus they are found to be more stupid, and limited in their faculties, in proportion to the length of the neck; and, consequently, the distance of the heart from the brain, and *vice versa*. This law seems applicable even to the human tended them to salamanders, tadpoles, acquatic and land frogs, and to grey and green coloured

human species. It seldom happens that persons whose strait and lengthened chest sustains a long slender neck, are celebrated for scientific attainments; at least, it may safely be asserted, that the most distinguished men of science have, in general, very short necks, and that their heads almost touch their shoulders; in consequence of this circumstance, they ordinarily die of apoplexy.—VI. In considering the scale of animated beings, the vascular system claims a prior regard to that of the nerves, and comes immediately after the digestive organs.—VII. The nerves, by means of their infinite ramifications, maintain the most intimate connexion with the different parts of the body: but the sanguiferous system, composed of a prodigious number of arteries and veins, has, likewise a very close relation with the various organs, to which it supplies the matter necessary for increasing their mass, repairing their losses, &c.—VIII. The argument which makes most strongly for the nerves, consists in the rapidity of their action—a rapidity which nearly equals that of lightning; whereas the functions of the vascular system, being subordinate to the course of a fluid, the momentum and velocity of which are incessantly varied by a thousand obstacles, must be performed in a very slow and progressive manner.

The illustrations which I might give of these different propositions, would far exceed the limits of a note. I shall, therefore, reserve them for a particular essay on the reciprocal action of the organic systems.

lizards,

lizards. He likewise made some very important researches respecting the motion of the blood in the chick *in ovo.* Their importance is well known. We formerly could only apply to the circulation of warm blood animals, facts inferred from analogy in very many instances erroneous. But we are now enabled to reason from positive and direct observations. We ought not, however, to disregard those which have been afforded us by cold-blooded animals, since the results of the experiments on the chick *in ovo* have not been very widely different.

Spallanzani, in making his experiments, used the anatomical instrument of Lyonet. It possesses this advantage over the ordinary microscope, that it shews the blood-vessels by a refracted light, and very nearly in their natural situation.

The work which he published on this subject, procured to the author the following very honourable dedication:

Illustrissimo viro Lazzaro Spallanzani, summo naturæ in minimis et difficillimis, indagatori, ob ejus

*ejus in veri finibus extendendis merita, D. D. D. Hallerus**.

§ XI.

The microscope has opened a new world to our view. Seen through it, fluids of every kind are found teeming with thousands of corpuscules, which are all in motion, darting backwards and forwards, and whirling round in all directions What is the nature of these corpuscules? Are they the elements of decomposed matter? Do they constitute the integrant bases of bodies? Are we to regard them as inert and passive particles, consisting of earthy, saline and metallic principles, which float at random, and attach themselves to those substances with which they have the strongest affinity? Shall we find in these corpuscules the subtle matter of Descartes, or the monades of Leibnitz? Or ought we, rather to rank them among beings endowed with inherent activity, spontaneous motion and vitality? If we admit them to this rank, do they possess a peculiar organization and characteristic usages and habits? Do they form a distinct class of animals? or are we to consider them as

* Phys. t. IV edit. in 8vo.

exhibiting

exhibiting the earliest stage, the primitive infancy, of individuals belonging to species already known, and as indicating in their various appearances and movements, the future propensities, character, form and corporeal powers, of these different individuals? All these opinions have, in their turn, been advanced, maintained, and combated.

Buffon assigns to the infusory corpuscules, nothing more than an inert and passive movement. He does not perceive in them any constant form, or determinate organization. The parts of which they seem to consist, are, in his opinion, the effect of optical illusion: in short, these supposed animals, he conceives to be mere organic moleculæ, or the constituent principles of bodies, subordinate to the law of a force which acts upon every particle of matter; an interior mould which determines their figure, relative properties, quantity, distance, bulk, and mass. This system is strongly maintained by an English naturalist, who supports it with a very specious train of microscopic experiments. He explodes, however, the vague and insignificant expression of *interior mould*, and substitutes that of *vegetative force*. But, if these atoms, or moleculæ discover characteristic marks of an active and uniform vitality, and are connected with animals by the possession of similar properties, can we refuse them a place in the immense series of living beings*? Do not the experiments of Spallanzani prove the existence of those characteristic marks, and those properties? And do they not establish, in an incontestible manner, the animality of the corpuscules of infusion? Let us take a brief view of his experiments, upon this subject.

* *Opuscoli di fisica animale e vegetabile, con due lettere del-sig. Bonnet.* Modena, 1776, 2 vol. in 8vo.

The first volume of this work is merely an enlargement of an essay which Spallanzani published in 1767, under the title of "*Saggio di osservazioni microscopiche, relative al sistema della generazione, d' sig. Needham et Buffon*, &c." Spallanzani must, therefore, have turned his attention to the animalcula infusoria long before the publication of his opuscules or even his essay, as I have already observed, in the note page 13, on the authority of a letter from Needham to Bonnett: and it was consequently unjust to accuse him of merely copying Meyer's work upon the animalcules of infusion. This work appeared it is true, before the publication of the opuscules, but not until long after that of the essay, which contains the general results of the Experiments, that are detailed and repeated in the former production.

Motion.—

Motion.—The corpuscules of infusion have no uniform and regular motion. Some move in an undulating manner, like eels; others bend and twist themselves in a thousand different ways. Some of them make their way with rapidity; others more slowly: several spin briskly round their own centers; numbers move by leaps, darting in all directions, and describing in their course, right lines, curves, circles, &c. and a few classes are seen in a middle state between motion and rest. In general, they pursue, fly from, each other; suddenly change their course, and proceed in an opposite direction; voluntarily, and without the smallest external shock, pass from a state of rest to a state of motion; and are found to crowd most numerously to those parts where the liquid of infusion is most abundant.

Organization.—They have fins, a mouth, a stomach and air-bladders; but they exhibit neither a heart nor blood vessels. Their forms are oval, long, globular, cruciform, and generally of the most fantastic and irregular appearance.

Aliment.—They are carniverous, ferocious and ravenous, eagerly dispute their prey with each other, and produce in the water a kind of whirlpool, which brings their food to their mouths.

mouths. This generally consists of a weaker individual. The smaller are always the victims of the larger and stronger animals; this is a constant law of nature, and holds good in the microscope, equally with every other department of nature.

Element.—Water is their natural element; deprived of it, they abate their activity, become stationary, and perish.

Temperature.—They perish in a heat of about 33, 34, or 35 degrees; tadpoles, frogs and salamanders cannot support a higher temperature. They are not all equally sensible to cold; some of them perishing at the freezing point, and others at 5, 7, 9 degrees below it. Insects are affected in a similar manner.

Odours.—Odours and liquors which are poisonous to insects, are equally fatal to the animalcules of infusion. They perish, when exposed to the exhalations of camphire, the smoke of turpentine, tobacco and sulphur; or when plunged into oily, saline and spirituous liquors.

Electricity.

Electricity.—The electrical spark is a thunder-clap to the animalcules of infusion; not one of them survives the explosion.

Air.—They perish in the vacuum of the air-pump; and all signs of life are suspended in air which they have breathed for a considerable time. What is the cause of their death in this case? It does not proceed from their irritability being weakened, nor from the diminished elasticity of the air: neither can it be attributed to the decomposition of their blood; for several animals have been found to live a pretty long time, after being entirely deprived of that fluid. Is there, at that moment, a new gas produced, which, acting directly on the nerves, induces those convulsions under which the animal expires? Such was the opinion of our author, and it was not very far from the truth; but the chemistry of the time did not admit of a nearer approach to it*.

Generation.—

* All animals perish in air which is not occasionally renovated; there is no difference but in their dying more or less suddenly. Until very lately, the most ridiculous explanation was given of this fact. It was pretended, that the air losing its elasticity, and being then incapable of re-acting upon the lungs, these organs collapse, and

Generation.—They multiply at all seasons; but they are produced in greater numbers, during the summer. Heat forwards their reproduction; cold retards it; a temperate state of the atmosphere is the most favourable to their propagation. They engender in various ways; but most frequently by division, longitudinal, transverse, cruciform, &c. The number of their young is not always alike; it rarely happens that many are brought forth at the same time; but their fecundity is, notwithstanding, prodigious, and the births succeed each other with inconceivable rapidity. These are, sometimes, followed by death; which, indeed, always happens in the

and by that means suspend the circulation of the blood, &c. At present, this phenomenon is regarded as an undoubted chemical effect. But should not the nervous re-action, which so manifestly discovers itself by the convulsions of the animals subjected to the experiment, be considered as one of the primary causes of their death? In an accurate physiological explanation, ought we not to combine this cause with the change which takes place in the sanguineous fluid? Are we not even compelled to admit this re-action of the nerves, if it be true, as it most certainly is, that it proceeds from the direct and immediate excitement of deleterious gases, and that disorders of the nerves occasion death more suddenly than the decomposition of the blood and the other humours?

case of multiplication by disruption, without leaving behind the smallest vestige of the parent, whose organs are instantly changed into so many new animals. These are oviparous and viviparous animalcules: the carnivorous species belong to the latter class; their young may be easily distinguished. How do they propagate? Have they genital parts? And do they copulate with each other? It does not appear that they do; they engender solitarily, one by one; and almost all of them are hermaphrodites.

Resurrection.—The animalcules of infusion present us with a spectacle still more astonishing. Taken out of the element, which is natural and necessary to their existence, they perish, dry up, lose every appearance of life, and exhibit only an earthy, friable, passive, and inanimate particle of matter*. But the moment they are again put into

* This state of death must not be confounded with the periodical torpor to which different animals are subject. These, it is true, lose the use of the parts and their functions, but their organization remains entire; their fluids are merely reduced in quantity, or in a state of stagnation, sometimes they even continue their motion; and their solids retain a flexibility which renders them susceptible of again exercising their proper action. The animalcules

into a liquid, or wetted with a single drop of water, they resume their organic conformation; gradually recover themselves; become sensible as before, to the action of stimulants; and, once more, offer to our view all the marks of motion and life.—

The second volume of the smaller tracts, is especially appropriated to the examination of spermatic worms. On this subject, Spallanzani corrects a number of errors which had escaped Lewenhoek; he refutes Linnæus, who regarded these worms as saline particles, and Buffon, who conceived them to be mere constituent and organic moleculæ. He contends, on the contrary, that these worms are real animals. The semen is their natural element; and, they perish in

animalcules of infusion, on the other hand, are reduced to a state of complete disorganization, similar, in all respects, to the actual death of other animals; and if, without a new creation, or apparent multiplication, their organs resume their original action, execute the same movements, in a word, recover life, what other name can be given to this act, than that of a real *resurrection?*

Felix Fontana will, in a short time, publish a work upon the *resurrection of animals*, which will convince the most incredulous readers.

 every

every other. Like the animalcules of infusion, they are sensible to the operation of cold, heat, odours, electricity, &c. They have no discoverable mode of reproduction, and it is not known whether they are viviparous or oviparous.

Spallanzani then gives us the history of particular classes of the animalcules of infusion, such as the *Tardigradi* and *Rotiferi;* and, after that, some very curious researches, respecting the degree of heat favourable, or detrimental, to the evolution of germs and eggs, and respecting different kinds of moulds, which several naturalists have erroneously regarded as the link which unites the vegetable with the mineral kingdom.

§ XII.

" The moment I read the work of the Abbe Spallanzani on digestion, I conceived an intention of translating it. On perusing it a second time, my mind was entirely occupied with the means of executing my design. These researches are, perhaps, one of the most valuable productions of which natural history can boast, and one of the most accurate and ingenious commentaries which have ever been made upon the works of nature. This excellent book, when perused with

with attention, interests the reader, as much by the manner in which it is composed, as by the subject which it treats. The manner is that of one of the greatest naturalists of Europe, who studies with superior talent a subject involved in the deepest obscurity; but which he has the art of placing in the strongest and clearest light. There are but very few books which are so well calculated to inspire a taste for the study of nature, or furnish so many aids for prosecuting it with success. It is, in fact, a system of logic for the naturalist, and the guide, which, beyond all others, ought to be followed by those who apply themselves to the study of physiology."

Such is the language of a translator worthy of the original*. There are, indeed, but few compositions which contain an assemblage of facts, so numerous, so conclusive, and so well arranged. What subject can be more interesting than that of digestion? and with what wonderful address does our author consult nature, and receive her responses? The discriminative choice of his experiments, the simplicity of his processes, the carefulness with which he conducted them, the

* *Dissertazioni di fisica animale e vegetabile.*—Modena, 1780, 2 vols. in 8vo.

logical closeness of his deductions—every thing, in a word, combined to render this performance a finished model of the experimental art. In no part of it can we suspect him of error, prejudice, or partiality. The author forms no system, no hypothesis: he gives a correct statement of facts, and the sum total which results from them is the only theory he admits.

We shall not enter upon an analysis of a book which is in universal circulation. It will be sufficient to observe, that the author proves, that the gastric juice is the direct and immediate agent of digestion; that it acts neither in the way of fermentation, nor putrefaction, but produces in the aliments, a real dissolution of their principles; and that it is subordinate to the various laws of affinity, &c. &c.

This work is one of those which did the highest honour to Spallanzani. It obtained the approbation of the greater part of the naturalists of every country, those of Italy excepted: and why did they decide upon its merits with greater severity and injustice than the others? Whence comes their refusal to allow their countryman the glory of one of the master-pieces of the human mind? Reaumur, it is true, was the first who trod the same path; but was not Newton preceded by Descartes? What, I would farther ask, is there in common between the tubes invented by Stephens, and the use to which they were applied by the physiologist of Pavia?—And you, John Hunter, who have enriched physiology and especially anatomy with so many valuable facts—what was the motive of your bitter satire against our author? "He is not an anatomist*," say you; but he did not pretend to give an anatomical work. On the contrary, he has avoided, as much as possible, going into any anatomical details. Those which appeared indispensable to his purpose, he has copied from Haller; and, surely, you cannot object to so well informed a guide.—"He has not observed digestion on a scale sufficiently large."—Yet he has examined it in every class of animals, from the creeping insect to the human being.—"From a few particular facts, he has drawn consequences

* *Observations on certain parts of the animal œconomy*, by John Hunter, 1786. London, &c.

Spallanzani answered this work, in a pamphlet entitled, *Lettera Apologetica in risposta alle osservazioni sulla digestione, del Sig. Giovani Hunter*. Milan, 1788, in 4to.

too general*."—A few particular facts! Surely you did not mean to say, that those which he brings

* This reproach is not without some foundation. In fact, though the process of digestion is common to all animals, and the stomach is its principal organ, it is probable that this function does not operate in the different individuals with that uniformity which has been imagined. The difference in the structure, position, and organic relations of the stomach, habit, climate, variety of aliments, and an infinite number of other circumstances, may give results applicable to a few species, but not to all; and this has been shewn by Hunter beyond the possibility of doubt. He agrees, however, with Spallanzani, that the gastric juice is the principal cause of digestion, but he supposes that it acts by fermentation.

There is another accusation which may be brought against Spallanzani with still greater justice. This writer considers digestion only as it results from the gastric juices and their solvent properties. His enquiries are exclusively confined to the part which they perform in that process. He does not take the least notice of that force which decomposes, changes, modifies, augments, or diminishes, prolongs or suspends, and stops the effects of digestion.—I mean the action of the nervous system. Yet who is there that does not daily experience its good or bad effects? Physiologists were surprised at so remarkable an omission on the part of Spallanzani. In truth, the action of the nerves cannot be submitted to the brings forward are not sufficiently numerous. You might, with greater justice, have accused him,

the crucible of the chemist, nor are the efforts of mechanical industry sufficient to attain a complete knowledge of its wonderful effects. It has, however, its mode, and peculiar laws, and its influence in the process of digestion is very powerfully discernible. "What is the reason," said I, one day, to Spallanzani, "that you have not examined a subject so deserving of your attention? The French, who take so proud and scrupulous an interest in that part of the science of the animal economy, which treats of the phenomena of life—a science which they have created, or, at least, defended so successfully against the attacks of a too celebrated sect*—find much fault with you for this inadvertence."—"It is true," replied he, "that I have not spoken of the effects of the nervous system on digestion; but does it follow that I reject them? Why give such an interpretation to my silence? What is there in my researches to authorise it? At most, my work can be regarded only as incomplete, and I know that it is so in many respects. I entered into too wide a field.—I have been blamed for not giving a complete treatise on digestion. I must confess that I never had patience enough to transcribe, and dispose in sections and chapters, the experiments, opinions, and

* I here allude to the sect of the mechanicians, so powerfully combated by the French physicians, and particularly by those of the University of Montpellier; Borden, Barthes, Fouquet, Grimaud, Dumas, &c.

writings

him, as others have done, of going a little too far in this respect. Would you pretend to assert, that particular facts obtained from an examination of each species, cannot afford results common to all the classes? But, if all animals possess gastric juices; if these juices are, in all, the principal agent of digestion; if they operate in the same manner, and produce the same effects; how

writings of others. I conceived it was enough to digest my own thoughts, without endeavouring to arrange those of others."—"Do you," added he, in an extremely flattering and encouraging manner, "who apply so much to the study of physiology, make some enquiries respecting the influence of the nervous system on digestion." This mode of invitation was to me the same as a command. I instantly sketched out a plan of experiments, which I communicated to him; he thought them worthy of being carried into execution. Some trials have been already made, and they seem to prove that the action of the nerves has no direct influence on the aliments, but that it solely exercises its force in the secretion of the gastric juices, and that the accomplishment of this secretion seems even to be its exclusive object, &c. &c. This remarkable corollary must therefore be deduced from them, that, in the choice of aliments, it is as necessary to consider their affinity with the sensibility of the nerves, as with the constituent principles of the gastric juices; the former determining the secretion of the juices; the latter, the dissolution or digestion of the aliments, &c. &c.

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can we avoid inferring from these facts, in some measure, individual, but yet common to all the species, the most extensive consequence, a general corollary, applying to the different classes?—And if it is incumbent on the physiologist to study nature in every point of view; if he ought to possess the most varied attainments; who better merits that title than Spallanzani, who, alternately, and with equal distinction, officiated as professor of mathematics, experimental phylosophy, ancient and modern languages, and natural history—-than the man to whom we owe the most precious researches into the principal functions of the animal economy?

§ XIII.

What is the mechanism of that act with which is conjoined the propagation of living beings? Whence those tender sentiments which precede those lively emotions which accompany it? Why that mystery with which it surrounds itself, that silence it loves, that solitude it courts, that secrecy it exacts? Is it that nature, jealous of the most exquisite of her prerogatives, dreads their being invaded by a rash surprise?—But what stoic, however frigid, amidst the convulsions which agitate the inmost springs of the human frame

frame, would, or rather could, dare to take a view of himself, calmly collect his thoughts, meditate, reflect, and observe?—

Upon the subject of generation, the ancients have transmitted nothing but hypothetical reasonings. Harvey, Malpighi, Graaf, and Vallisnieri, have removed a part of the veil which covered it. Haller has obtained more positive and satisfactory results, and established this wonderful doctrine; that the fœtus belongs to the female, and pre-exists in the uterus. Every one knows that he supports this opinion by the following facts: The membranes which cover the internal and external surface of the yolk of the egg, are merely a continuation of those which line the stomach and intestines of the chick. The vessels of the yolk anastomose with those of the chick; the blood passes from the one to the other; it flows in common and uninterrupted channels; it is propelled by the same force, &c. &c. The yolk, therefore, must constitute an essential part of the chick *in ovo,* and must be intimately connected with its organization. But whether it be, or be not, impregnated in the egg, it is clear that the chick must exist even previously to copulation: for what purpose would the membranes and vessels of the yolk serve, without those of the chick, of which they are merely an expansion and prolongation? And can these vessels and membranes exist without the concurrence of the parts necessary to their formation, namely, the stomach, heart, nerves, &c.

Spallanzani proceeded a great deal farther in this obscure path. He found, at the very outset, that the supposed eggs of salamanders, frogs, and toads, are nothimg else than so many fœtuses existing in a more diminutive form in the ovaries of the females, that the fœtuses whether fecundated or not, possess the same structure; and consequently, that they must exist prior to the act of fecundation. He made a like discovery with respect to the amnion and umbilical cord, and fully satisfied himself, that these parts exist before copulation. Nor did he stop there: he soon discovered that the fecundation of tadpoles* takes place out of the body of the female.

* Spallanzani observed this mode of fecundation out of the body of the female, in aquatic and land-frogs, aquatic salamanders, and different sorts of toads. The fecundation of salamanders, however, does not take place entirely without the body of the female, for the semen of the male penetrates a little into her vagina. Roesel had remarked, before Spallanzani, that the fecundation of the land-frog takes place without the uterus.

male. As the latter excludes the eggs, or rather the fœtuses, the male bedews them with his sperm. Those on which the liquor falls, vivify and gradually evolve themselves; while those which are not sprinkled with it, die. The same fate awaits those which issue from the uterus, without the subsequent act of copulation. Not one of them escapes the rigour of this law. Spallanzani convinced himself of this fact in a very ingenious manner. Having remarked that the fœtuses issue from the uterus, one by one, with the umbilical cord, to which they are separately attached, he took two parts of this cord, the one sprinkled with the seminal fluid, the other not, and placed both of them in a situation equally favourable to evolution: the fecundated fœtuses produced frogs; the others, without a single exception, remained barren and perished.

A discovery so curious must naturally have suggested the idea of artificial fecundation. Naturalists had, hitherto, failed in this bold experiment. But nature had betrayed herself, by furnishing an instance of fecundation out of the body of the female. The process adopted by our observer may be easily conjectured: he took some eggs which a female had laid, without copulation, wetted them with the semen of a male,

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and placed them in a situation favourable to incubation. Six days afterwards, the eggs produced living tadpoles, in every respect similar to those which are generated in the natural way. Those, on the other hand, which had not been impregnated with the sperm, gave no signs of life, and soon putrefied. A very small quantity of sperm is sufficient to fecundate a number of eggs. A single drop, which is scarcely visible, will produce the same effects as a very considerable quantity. Water does not perceptibly diminish its prolific power. Three grains were found to retain all their efficacy, though mixed with eighteen ounces of water; and on another occasion, the same quantity was capable of vivifying several fœtuses, when dissolved in twenty-two pounds of water. Let us beware of attributing the qualities of the semen to a volatile principle, an *aura seminalis*. Spallanzani placed a number of fœtuses, at the nearest possible distance from the seminal liquor, without obtaining a single instance of fecundation. An immediate contact was always necessary to produce that effect, and it appeared that the fecundating virtue resides in the thicker and more solid part of the seminal elements.

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The sperm, when mixed with a small quantity of water, retains its activity much longer than in a pure state. To mix it in this manner, is, indeed, indispensable to the fecundation of the eggs of salamanders.

Neither the blood, bile, urine, nor saliva, destroy the prolific power of the semen; yet none of them can supply its place. This is the case also with several other fluids. The electric shock, however, appears to add somewhat to its activity.

The semen is equally capable of fecundation, whether it contains spermatic worms, or not. The urine, which is poisonous to them, does not, in the smallest degree, impede the process of generation. What, then, must we think of the hypothesis of Lewenhoek, which is founded on the existence of spermatic worms? or of the theory of Buffon, depending on organic moleculæ, which are nothing else than these very worms?

The greater part of Spallanzani's experiments respecting artificial generation were performed on different kinds of frogs, toads, and salamanders,

ders. He likewise succeeded in fecundating a silk-worm in the same manner; an experiment which had been tried in vain by Malpighi.

But of all these artificial fecundations, the most astonishing is that which he effected on a bitch. Having injected into her vagina nineteen grains of semen taken from a dog of the same breed, he had the satisfaction, after the ordinary time of gestation, of seeing her bring forth several young whelps, likewise, of the same race, and which had attained their full growth. It is unnecessary to add, that every precaution was taken, which could put the experiment beyond the reach of ambiguity or suspicion*.

Spallanzani attempted in vain to fecundate the eggs of a frog with the semen of a toad; and he was equally unsuccessful on wetting the germs

* Doctor Rossi, of Pisa, successfully repeated the same experiment. See *Giornale dé letterati di Pisa, tom. XLV. in* 1782; see also a letter from Spallanzani to Rossi in the same volume of that work.

Chevalier Joseph Bufalini of Cesena, also obtained a similar result; and even succeeded in the artificial fecundation of several fishes.—*Opuscole scelti di Milano, tom. XIV. in* 1791.

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of a salamander with the sperm of a frog: astonishing precaution of nature to prevent disturbing the harmony of the various species, and augmenting the number of races and mules!

The farina of the stamina is, beyond doubt, the vivifying principle of the germs contained in the ovary of the pistils. It is a general law of nature, that the process of generation cannot take place without the union of the sexes; but from this rule there are some very striking exceptions among grubs, polypi, and the animalcules of infusion. Spallanzani discovered, that the same irregularity obtains in the vegetable kingdom. He observed the seeds of different kinds of hemp and gourds produce, without the intervention of the stamina, embryos which grew up to maturity.

A result so singular must have given great offence to the sexual botanists. Our author, was aware of this; and he, therefore, conducted his experiments with redoubled care and attention. Still, however, he was not able to escape the shafts of envy and calumny. His opponents did not controvert the result of his experiments; they went farther—they asserted that he never made them. This was to attack, at once, his reputation, and his probity; and it was, surely, more than sufficient to excite his just indignation*.

§ XIV.

Spallanzani, besides being professor of natural history, was likewise charged with the superintendence of the museum; and a yearly sum was placed at his disposal, for the purpose of making such purchases as he should think necessary to its embellishment. He negociated the purchase of Goez's collection of worms, a collection unequalled in its kind, and from which that celebrated Dutchman composed the work which he published on this subject. But the greater part

* I here allude to Canon Volta, of Mantua, whom the reader must not imagine to be the same with the immortal Alexander Volta, of Como, professor of experimental philosophy in the university of Pavia. The former inserted in the transactions of the academy of Mantua a pretty long paper, in which he asserts, that Spallanzani never made the experiments relative to the fecundation of plants. Nothing but the publicity of this paper could provoke Spallanzani to take notice of it. He replied to it with much acrimony and vehemence, in a letter addressed to a friend at Mantua—*Lettera a un amico di Mantova Pavia,* in 8vo. It will be seen in the sequel, that this dispute proceeded from a former quarrel of, by far, too virulent a nature.

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of the curiosities which adorn the cabinet of Pavia, were collected by Spallanzani himself. Strictly speaking, indeed, he may be said to have laid the first foundation of that superb establishment; for, before his appointment, it contained a few mutilated relics only of the three kingdoms of nature, thrown together without order or method. Instead of this chaos, it now presents to the admiration of the lovers of nature, the most complete and best arranged and distributed collection in all Italy, without even excepting those of Bologna and Florence. It was during the vacations, that Spallanzani devoted himself to this new employment, which was no less laborious than interesting. At one time, making an excursion to the Alps, and Appenine mountains, and, at another, directing his course towards the borders of the Adriatic and Ægean seas, he always returned, loaded with the richest spoils; nor did he ever omit making such enquiries on the spot as might tend to elucidate various obscurities in the science of nature. Thus in the gulf of Spezzia, at Porto Venere, and in different parts of the shores of the Mediterranean, he added a multitude of valuable facts to the history of the torpedo*, molluscas,

* See an abstract of a letter from Spallanzani, inserted in vol. VI. of the select Opuscules of Milan, in 4to, and

molluscas, halcyons, millepores, madrepores, medusas, corals, the animals which occasion the luminous appearance of the sea by night, and several other marine and fossile productions*.

In 1779 he went through a part of Switzerland, passed several days at Geneva with his il-

and in the Abbe Rosier's Journal of Physics, 1783. Spallanzani there traces some new relations between the electric fluid, and that which occasions the shock of the torpedo. He asserts, in opposition to Schilling, that the magnet does not raise the torpedos, and that they even do not fix upon it; and, in opposition to Linneus, that the shock of the Torpedo is felt, whether the breath be kept in or not; that the animal is not poisonous, and that it has not real lungs, &c.

* *Lettere due relative a diverse produzioni marine e diversi ogetti fossili e montani, al Sig. Carlo Bonnet. Societ. Ital. di Verona, tom. II.* 1784, and in Rosier's Journal of Physics, tomes XXVIII. and XXIX. 1796. He enters into the most copious details respecting the cause of the shining appearance in the sea by night, and he confirms the opinion, that it proceeds from the phosphorescence of an infinite multitude of animalcules floating on the surface of the water. He enquires whether their light is produced by a particular organ; whether it sparkles constantly or periodically, and when the animalcules are out of the water; whether they be oviparous, or viviparous, &c. &c.

lustrious friends, Bonnet, Trembley, Saussure, and Senebier; and, having thence proceeded to Berne, to pay a visit to the widow of the celebrated Haller, he returned home by Mount St. Gothard.

In 1781, he sailed along the borders of the Mediterranean from Leghorn to Marseilles, where he remained six weeks.

In 1782 and 1783, he travelled in Istria, along the shores of the Adriatic, through the Euganean mountains, &c. &c.

§ XV.

The longest of Spallanzani's voyages, was that which he made to Constantinople. He embarked at Venice in the month of August, 1785, with the Chevalier Zugliani, who was appointed ambassador from the Venetian Republic to the Ottoman court. Off the coast of Istria, a water-spout * attracted the attention of the two passengers. They observed that this phenomenon neither raised nor absorbed the waters of the

* See his description of it in Brugnatelli's "Bibliotheque Physique d'Europe;" tom. VII. 1786.

sea.

sea. It is merely a current of air confined in a vaporous tunnel, which precipitates itself from the clouds to the surface of the waves. This current appears to be the primary effect of several opposite winds, which, rushing violently against each other, communicate to the cloud a kind of whirling motion. The vaporous canal is probably produced by a whirlwind, which, penetrates with great force into the body of the cloud, dilates the lower part, and thus enveloping itself, suddenly darts down with it, sometimes to the lower regions of the atmosphere, and sometimes to the very surface of the sea. A similar meteor which occurred in the same tract, about a month before, broke upon a vessel and dashed her in pieces.

The vessel having put into Corfou, Spallanzani, to whom time was precious, took the opportunity of visiting this island. In vain did he search after the palace of Alcinous, and his renowned gardens, which are celebrated by Homer. Time has effaced the very traces of them; it has respected nothing but the fountain which refreshed and fertilized them.

They set sail, and Cephalonia and Zante were soon left behind. But suddenly the sky was darkened with clouds, the lightning flashed, the thunder rolled, the sea foamed, and the vessel was driven to land. It was Cerigo, the ancient Cythera.—Where is the abode of the goddess? Where her temples, altars, priests, and nymphs? —Ye, who search after pleasure, touch not at Cythera. The queen of love has abandoned this isle; it is no longer inhabited but by wretched savages; and nothing is to be seen in it but rubbish, ruins, bones, and substances, which have undergone the action of fire.—Was this the state of Cythera in the time of the Greeks? Or has this change of appearance been produced by the fury of volcanos, of which it exhibits a thousand traces*?—The vessel proceeded on her voyage. What must have been the reflections of our traveller as he sailed along the Archipelago? Here flourished Athens; there Lacedæmon; at this place crossed the army of Xerxes; beyond it, the conqueror of Asia disembarked his invincible

* This was Spallanzani's opinion;—See his letter from Pavia to Chevalier Lorna, entituled, "*Osservazioni fisiche instituite nell' isola di Citera, oggidi Cerigo Societ. Ital. di Veron. tom. III.* 1786.—Spallanzani discovered in this island a small hill, composed almost entirely of human bones. He conceived that it was one of the cemeteries of the ancients.

phalanxes; a little farther, Rome lost her liberty; and here Octavius confirmed his despotic sway.

Spallanzani arrived at Constantinople on the 31st of October, and continued there eleven months.—I should gladly follow him, did my limits permit me, in his excursions amidst that celebrated city and its delightful environs —to the isles of Principi and Calki; in the former of which he discovered a mine of iron, and in the latter a mine of copper — along the shores of the Black Sea, and across the mountains of Asia. With pleasure would I accompany him to that region on which the war sung by the first of poets has conferred immortal renown. With what reverence, with what religious curiosity, must he have visited the scenes where Patroclus expired in consequence of the wounds inflicted by Hector; where Achilles avenged the death of Patroclus; where Diomede imbrued his hands in the blood of the gods; and where the artful Ulysses appeased the dissensions which were so disastrous to the enterprize of the coalesced kings!

——————— Juvat ire et Dorica castra,
Desertosque videre locos, littusque relictum:
Hic Dolopum manus; hic sævus tendebat Achilles,
Classibus hic locus; hic acies certare solebant.*—

* Æneid, lib. II. v. 27. &c.

And

And who could be better qualified to discover the camp of the Greeks, the walls of the Trojans, and the particular scenes of their bravery, than the man who had so profoundly studied the works of Homer*?

Spallanzani left Constantinople on the 16th of August, 1786. The various productions which he had collected were put on board a Genoese vessel; and, accompanied by a faithful domestic, he himself, took the road to Germany, through Bulgaria, Wallachia, Transylvania, and Hungary. He frequently stopped, in his way, to examine those little known countries. He remained several days at Bucharest; the Governor† accommodated him with a lodging in his palace, and, on his setting out, gave him an escort of thirty soldiers as far as Hermanstadt.

* Spallanzani died without publishing his voyage to Constantinople. This work, however, was completed, and I have several times had the manuscript in my hands. It would probably have made its appearance in the course of this year, or, at farthest, after the publication of his experiments on respiration. It has been consigned to the care of men of taste and information, and the public will soon be gratified with a perusal of it.

† Maurocini, Hospodar of Wallachia.

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He made a much longer stay in Hungary, where he attentively explored the numerous and rich mines with which that province abounds, and made a very valuable collection of metals and minerals of different kinds.

At Vienna, Joseph II. received him with the most marked distinction, conversed several hours with him, and presented him with a medal of himself. The ministers, ambassadors, and most distinguished literary and scientific men of that city, honoured the naturalist with their visits. In vain had calumny sharpened her shafts; no one gave ear to the scandalous accusations which had been made against him; their falsehood was detected, and Spallanzani's innocence was proclaimed by an imperial edict*. He returned in triumph

* I shall here abstain from quoting any part of this edict, being averse to do any thing that might influence the passions and revive animosities. This silence will doubtless be approved of. It is sufficient to observe, that Spallanzani, accused of having taken away some curiosities from the cabinet of natural history, was declared innocent of the charge by a decree of the government; and his accuser, John Seraphin Volta, declared incapable of holding any employment in the university. With regard to the other persons affected by the same decree, I never

triumph to Pavia, after an absence of twenty-one months. His pupils testified, by the most eager demonstrations of joy, the pleasure with which they saw him come to resume his lectures, and their regret for having so long been deprived of them.

§ XVI.

Here a chasm occurs in the literary life of Spallanzani. Every preceding year had been distinguished by several publications, and the reader could scarcely follow him in his numerous researches. But, for three years from the present period, he gave the world nothing except a few occasional letters*. It does not even appear that

I never could believe that they took the smallest concern in the meditated disgrace of Spallanzani ; their openness of disposition, delicacy of feelings, and particularly their great merits, are to me the surest pledges that I am not mistaken. I have likewise met with many persons in Italy who gave me a very favourable account of the moral character of the Canon Volta. His talents may be estimated from his productions; and, among others, from his enquiries relative to the olfactory sense in birds, which have merited a place in the ingenious work of Scarpa, on the sense of hearing, smell, &c. &c.

* Among these letters, I ought to mention those which had a reference to the following anecdote:—A pretended

that he was occupied with any performances worthy of his reputation.—Perhaps, he was preparing himself for his travels in the two Sicilies.

§ XVII.

Spallanzani travelled in the two Sicilies, towards the end of the year 1788. But, before we accompany him to those happy climes, let us say a few words respecting the method which he pursued in his enquiries.—He studied volcanic products in the same manner as mountains are generally examined, in the aggregate of their masses, the intermixture and relative situation of

pretended animal was one day brought to Scopoli, who was assured that it had been seen alive, moving along, &c. The credulous professor thought he found in it the characters of an unknown species of worm, and drew up a description of it, which he dedicated to the celebrated Sir Joseph Banks; but it was very soon discovered that this new worm was nothing else than the trachea of a bird. This mistake which gave so much scope to criticism, furnished Spallanzani with the subject of two letters.—*(Lettere al Sig. Scopoli in Zoopoli,* 1788.*)*—extremely entertaining, which are now out of print. Spallanzani, after having been a believer in the magical rod of Pennet, made a recantation; and thence arose a very curious epistolary correspondence between him and Thouvenel, which was inserted in Brugnatelli's journals.

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the strata, the constituent parts of each stratum, &c. &c. The central elevation of the isles which he visited, likewise attracted his attention. This is, in general, the first sensible effect produced by subterraneous combustion; it is the spot which was first extruded from the bowels of the earth. There, the crater is frequently seen in an entire state, sometimes burning, but more generally marked with peculiar, characteristic, appearances. The shores of the isles, and of the volcanos washed by the sea, are equally deserving of investigation. Our observer sailed along their coasts in a small vessel, and repeatedly crossed them in all directions, examining, with the utmost coolness, their bursting sides, and falling rocks. How many facts might have been added to the science of orycthology, had preceding travellers possessed the same courage, and prosecuted similar enquiries with equal ardour!

Spallanzani arrived at Naples with the most eager impatience to visit Mount Vesuvius *. He was

* Vesuvius does not attract the attention of the Neapolitans, but during its grand eruptions. Habit renders them indifferent to the ordinary state of this volcano. Besides, experience has taught them, that the city of Naples has

was particulaily anxious to have a view of some grand eruption; and his curiosity was soon gratified. One of the sides of the volcano opened, and poured forth torrents of lava during the night. Spallanzani, being informed of the circumstance, immediately ascended the mountain amidst the glimmering light of the flames, with all the ardour of Pliny, and equally anxious to enjoy a near view of that frightful scene; but more fortunate than Pliny, he avoided the burning matters, and escaped the fury of the crater. He was prevented, however, from gaining the summit, by a shower of stones, and a thick emis-

has nothing to fear from its explosions. The inhabitants of Portici, and the adjacent villages, are the only persons who have any reason to dread so terrible a vicinage. They cannot forget the melancholy fate of Herculaneum, Pompeia, and the still more recent destruction of a great part of the Torre del Greco. Yet these events do not seem to have in the least added to their stock of prudence. New habitations are every year erected upon the same places. In 1796, I myself had occasion to see the inhabitants of a small town that had been destroyed in 1794, rebuilding their houses quite close to it, and with lava still smoaking. Certainly they could not fix upon a more beautiful eminence, a more fertile soil, or a more agreeable situation, but can all these advantages, countervail the dreadful prospect of a destruction, sooner or later inevitable.—NOT. LIT. SUR L'ITAL.

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sion of sulphureous vapours. He was therefore obliged to satisfy himself with observing the lava in motion, calculating its progress and degree of fluidity, estimating its heat, and ascertaining its composition, which he found to be a basis of Hornblend, of a dark grey colour, moderate hardness, dry to the touch, and giving a few sparks with steel.

The attention of our traveller was next directed to the famous Phlegrean fields, where the appearance of volcanoes extinguished, or inactive, surprises and terrifies the beholders, and where nature seems to have delighted in confounding all her elements, and in producing the most astonishing revolutions. He wandered over these scenes in company with the naturalist Breslack*. They examined together the lavas of Solfatara and the vapours which exhale

* This philosopher is advantageously known in Italy, by several essays in natural history. He has, at present, in the press, a very valuable work, on the mineralogy of volcanos in the environs of Naples, enriched with two magnificent maps, in which, besides the positions of craters, are laid down the most remarkable scites in that country. His delineation of the bay of Naples is much superior to that given in the beautiful maps of the royal calcography.

from

from them, the mephitis of the grotta del cane, the lake of Agnano, the mountain which rose from the bowels of the earth in forty-eight hours, Misena, Ischia, and Procida, that seem to have been reluctantly torn from the continent which daily recedes still farther from them.

Spallanzani then embarked for Sicily.—Vesuvius is no more to be compared with Etna, than the volcano of Lemery is with Vesuvius. Mount Etna occupies a space of about 180 miles, rises two miles above the level of the sea, and throws out its products to a distance of fifteen leagues: its crater is six miles in circumference.

The ascent of mount Etna is attended with a thousand difficulties. It is necessary to cross torrents of lava, to creep along on the scoriæ, to inhale repeated gusts of mephitic vapours, and to endure an alternate change of the most opposite temperatures. Spallanzani, however, surmounted all these obstacles, and arrived at the summit of the volcano. There, seated on the brink of the crater, he viewed, contemplated, and examined, with a mingled feeling of dread and admiration, the whole of that vast cavern, its form, sides, and bottom, the substances which are in a state of ebullition, those which are ejected, the vapours which exhale from it, their direction, &c. He looked around; and with surprize and astonishment he saw beneath him the immense mass of the mountain itself, extensive tracts, marked by the ravages of fire, the delicious Catanea, a vast expanse of sea, the whole of Sicily, its cities, mountains, and rivers, the Eolian isles, the volcanic Stromboli, Vulcano in flames, Lipari, Malta, &c.—"Seated," says he, "in the centre of this grand theatre, I contemplated, with delight, these different points of view; I experienced a satisfaction, a pleasure, an inexpressible extacy. Not a cloud was to be seen in the atmosphere; the sun was approaching his meridian; the thermometer stood at ten degrees; I found myself in the temperature most congenial to man; and the subtle air which I breathed, as if it had been entirely vital, produced in me such a degree of gaiety, vigour, and happiness, that I imagined myself transported into the celestial regions."

The Eolian Isles, that progeny of fire, have but very lately attracted the attention of philosophers. Dolomieu has given us an equally exact and entertaining description of them. But the field in which he reaped, was too extensive

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and fertile not to leave Spallanzani the hope, or even the certainty, of making some additional discoveries. He remained there thirty-five days. He was the first who visited Felicuda and Alicuda, in the character of a naturalist; but the volcanoes and minerals of these isles, were not the sole object of his enquiries. He examined their productions of every kind. He observed, and studied the manners of the inhabitants, their population, commerce, agriculture, industry and usages. These regions appear, at first sight, to be the abode of the most frightful misery. Their houses look more like so many nests stuck against the rocks, than human habitations. They are built of badly cemented lavas, and exhibit no appearance, either of external or internal regularity. Some of them, are lighted only by a pale glimmering, resembling that of caverns. Bread and a few wild fruits constitute almost the sole nourishment of the inhabitants. Sometimes, indeed, though very rarely, they have a little salted fish, which they wash down with pure water. Their repast is served occasionally upon little tables, but more frequently on the bare ground. Yet, if we look at the countenances of these islanders, we may trace in them an air of gaiety, contentment, and tranquillity, which forms a striking contrast with their wretchedness. Those viands, which to us appear so coarse or insipid, are exquisitely delicious to their taste. Those miserable huts, which the traveller at first regards with disgust and compassion, are to them equally dear as gilded canopies, and those barren and rugged rocks as attractive as the most smiling plains. Ulysses was not more attached to his Ithaca, than they to their Eolian isles.

Spallanzani returned to Messina, anxious to examine its straits, which are bordered with a reef of rocks on each side. Already he began to hear a sound, sometimes low muttering, and at others resembling the howling and barking of dogs: it proceeded from Scylla. These re-echoing and frightful noises which are heard a great way off, are occasioned by the violent agitation of the waves amidst the deep caverns of the rocks.

Homer and Virgil, therefore, in personifying Scylla have, with propriety, represented her as lying in ambuscade at the bottom of a vast cavern, and surrounded by howling wolves and barking dogs. But Scylla is no wise dangerous, except when the current runs from the south to the north, and the wind blows in the contrary direction; then, indeed, the vessel, acted upon by by two opposite forces, may be driven against the rocks, if the master be not a very skilful seaman, or if he neglects throwing out a signal for the pilots of Messina, who are always ready to give assistance*.

This devouring gulph, as it was generally supposed to be from Homer to Buffon, is not really a whirlpool. It does not absorb and disgorge the water three times a day, nor does it exhibit any whirling motion. The only thing which appears, is a continual agitation of the waves, alternately jetting up and sinking, dashing against each other and recoiling. When the current runs with very little force, even this movement ceases to be seen; and in the most violent tempests, far from swallowing up the passing vessels, Charybdis repels them to a very great distance.

The straits of Messina are, besides, famous for their fishery of coral, that ambiguous produc-

* Along the straits of Messina there are a number of expert and hardy pilots who are in readiness, day and night, to put off at the first signal; and, as the force of the current is not every where alike, they know how to choose the least dangerous parts, and to conduct safely into harbour the vessel which gives a signal of distress.

tion, which has been finally classed among animals, after having, by turns, been placed in each of the three kingdoms of nature. They likewise present the very curious spectacle of the fisheries of sword, and dog fish; an employment which forms a very lucrative branch of commerce for the inhabitants of Messina. In the same channel are found a Medusa of a peculiar organization; orbicular, somewhat convex, phosphoric, and with fringed edges; and a polypus, in which the circulation of the blood is visible. This is the only animal of the kind in which that phenomenon has, hitherto, been perceived.

Spallanzani here finished his travels in the two Sicilies. The journey from Naples to Genoa gave him an opportunity of visiting the lake of Orbitello, so well known for its eels, and the Elbe isles, celebrated for their mines of iron, which have been so well described by father Pini.

He did not examine the Appenines of Modena, until the autumn of 1790. The volcanoes of Barigazzo, the *salsès* of Reggio, Querzuola and Maino, and the petroleum of Monte Ziibo, were the objects which principally engaged his attention.

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The figure, form, extent, mass, and appearance of mineral substances, may be studied on the spot where they are found in their native state; but a knowledge of their constituent principles, requires a more serious and deliberate examination, which cannot be carried on but in a laboratory, and by the aid of a number of chemical operations. It was at Pavia that our learned professor re-examined, and minutely analyzed, the different volcanic products of which he had made so rich a collection. He estimated the quantity of iron which they contained; found in some a portion of muriatic acid, in others of ferrum speculare, ascertained the real origin of basaltes; determined, by the pyrometer of Wedgewood, the relative heat of culinary and volcanic fire; discovered that lavas are convertible into gases; and that these gases have a very powerful influence in the eruptions of volcanoes, the formation of hail, &c. &c.

Spallanzani's "Travels in the two Sicilies, and in some parts of the Appenines*," are particularly dedicated

* *Viaggi alle due Sicilie ed in alcune parti dell' Apennino. Pavia,* 1792, 6 *vol. in* 8*vo.*

Is it to a volcano in the air that we must attribute those showers of stones which have been known to fall at differen dedicated to volcanic mineralogy. We seldom meet with any thing in them, except lavas, scoriæ, pumice stones, enamels, ashes, sands, vitri-

ferent periods, and particularly in Tuscany, on the 16th of June, 1794? Several naturalists have adopted the affirmative. They conceive that the atmosphere holds in solution earthy, metallic, saline, bituminous, and sulphureous particles, which occasionally meeting in a cloud charged with the electrical fluid, take flame, burn, and are precipitated in the form of stones. Spallanzani had an entirely different opinion. He rejected the supposition of earthy, metallic substances, &c. as being completely gratuitous. According to his account, these stones have no appearance of vitrification. They contain particles of pyrites and crystallized quartz, products which cannot be accounted for on the supposition of an ærial volcano. He is of opinion that the stones must have been carried up, already formed from the surface of the earth itself by a whirlwind, or violent subterranean eruption. In support of this conjecture, he instances the storm at Padua, which swept into the air the whole of the roof of the public palace, and during which there fell a shower of hail-stones intermixed with a number of fresh blades of grass. He farther appeals to the testimony of Mercati and Lancisi, who assert that they had seen different showers of stones rising at first from the surface of the earth, and afterwards falling in the same manner as substances ejected by volcanoes. *Lettera sulla pioggia di sassi avenuta in Toscana nel* 16 *giogno del* 1794. *(Bib. ph. med. de Brugnatelli, tom.* 3. 1795.*)*

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fications, and the ravages of fire. Yet what region furnishes more matter for interesting reflections, and agreeable details *, than that "which nature seemed to have purposely created to afford the Romans a delicious retreat from the toils of conquering the world, or to make them forget that they had conquered it;" where the ashes of Virgil are deposited;—

Mantua me genuit, Calabri rapuêre, tenet nunc
Parthenope: Cecini pascua, rura, duces.

where Seneca was afraid to sleep for a single night; where Propertius suspected his Cynthia of infidelity the moment she arrived in it; where, in short, after a lapse of so many years, notwithstanding the vast changes which it has undergone, and, amidst ruins of every description, a modern traveller exclaims—"I, myself, feel that this abode, though so much changed by a succession of ages and the ravages of volcanoes, though reduced to a desert, though covered with ruins overhanging, or incessantly falling and disappearing amidst

* These details have been given by the learned French translators of Spallanzani's travels, Toscan and Duval. Their notes to the first vol. contain the most accurate, and, at the same time, most animated description of the environs of Naples. In reading it, I imagined I again enjoyed a view of the tomb of Virgil, the passage of Pausilippo, the Grotta del Cane, &c. &c.

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the waves—I, myself, feel that it is still pregnant with danger. It seems to me that this air has retained somewhat of its ancient contagious powers, from which it is not yet purified. I feel my mind softened by the prospects around, by the situation itself, and by that indefinitive faint shade, which successively extinguishes in the heavens, on the surface of the sea, the mountains, and the tops of the trees, the last glimmering of day. Above all, I feel my mind softened by that deep silence which, at intervals, diffuses itself along the shores, and, amidst which gradually swells upon the ear the soothing concert of the evening; composed of the melancholy noise of oars which beat the distant tide, the bleating of flocks scattered over the mountains, the murmurs of the waves as they gently die away upon the rocks, the rustling of the trees, among whose leaves the zephyrs wanton in eternal play—in a word, of all those indistinct sounds which wafted afar through the heavens, over the sea, and over the land, at this moment form, as it were, the inarticulate voice, the melodious respiration of slumbering nature."

§ XVIII.

Can the different parts which compose the animal machine, supply the place of each other in the functions which have been distributed to them in the primitive order of their organization, in proportion as they are connected by an intimate union or have a mutual communication of their habitudes, desires, and wants?—There are several instances of this kind of substitution, and the organs susceptible of it are pretty numerous. That this change, however, may be effected without violence, it is necessary that the action of the organs should be independent of any mechanical mode, or that they should be perfectly similar in structure. In the first case, nature unfettered by any particular organic disposition, may transfer the seat of her various acts, from one part of the body to another, in conformity to the laws of excitement. Thus the phenomena of vitality, which are as simple in their essence as varied in their effects, are found to exist in systems of a very different structure, because they are not connected with organic combinations, and are susceptible of changing place and assuming new modifications, according to the application of the stimulants which determine their activity*. Hence proceeds an actual change of direction

* It is my opinion that each function of the animal economy is composed of a three-fold action, chemical, mechanical,

rection in the vital force, from or towards, the head, stomach, genital parts, &c. &c. in consequence of the more active exercise; that is, the more powerful excitement of the respective organs. In the second case, which occurs but very rarely, the sameness of means produces a conformity of effects. The viscera, for example, which give out a mucous secretion, such as the bladder, the pituitary membrane, and the intestines, frequently supply the offices of each other; because the vessels of secretion with which they are furnished are similar in disposi-

mechanical, and vital *; that the phenomena belonging to the latter, are entirely independent of organization; that they are not exclusively connected with any particular system of organs; that they affect all the parts; that they are essentially erratic, being momentarily resident in this or that viscus, in consequence only of the laws of excitement, or the force of stimulants. These laws are acknowledged and attended to in the practice of some physicians, but I have not seen them included in any work upon physiology. I shall explain a few of these laws, which have been suggested to me by Brown, in a physiological essay, the materials of which I am incessantly occupied in collecting and arranging.

* *See le Plan du Manuel du physiologiste, ou Propositione fondamentales de la science de l'economie animale. Metz, an.* 5.

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tion, and the humour they secrete is composed of the same elements. But no kind of change or substitution can take place in the functions performed by organs, which are subordinate to a special mechanism, and rigorously connected with the external objects which support that mechanism. Thus the eye sees, because it possesses an organization fitted to receive the impression of the luminous fluid; but it cannot hear, because its structure is not adapted to the collection of sounds. In like manner, the taste cannot supply the place of the sense of smelling, because the tongue cannot receive the excitement of a sufficient number of the volatile odoriferous particles, so as to transmit it to the *sensorium commune.*

What then are we to think of the bat; which, notwithstanding the loss of its eyes*, perceives the objects that are in its way, avoids them, and afterwards continues its flight in the same direction as before? This animal is not furnished with a sixth sense; anatomy, at least discovers

* *Lettera sopra il sospetto di un nuovo senso nei, pipistrelli,* &c.

Spallanzani's experiments have been repeated with like success in Italy, France, and Germany.

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no indication of it, and analogy cannot bear us out in such a supposition. What other sense can supply the place of sight in the bat? Is it that of taste, smell, touch, or hearing?

The touch!—However exquisite we may suppose this sense, it surely cannot inform the bat of the situation, sometimes at a considerable distance of a ceiling, wall, window, &c. and, besides, if the extremities be covered over with varnish, the animal will still fly in its usual manner.

The smell!—This sense may, indeed, be of some utility. It is certain that a bat, deprived of its eyes, has a quicker perception of the proximity of a living being, than of an inanimate body. Yet, if the nostrils be perfectly shut, it is found that the bat avoids as before the obstacles which intercept its progress. In this experiment, however, the animal soon perishes from the difficulty of respiration.

The taste!—The partial, or total, destruction of the tongue, which is the principal instrument of this sense, does not prevent the bat from proceeding in the same manner, as when it has both its eyes.

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The hearing!—The result of several trials equally excluded this sense; but some more accurate experiments, made by Jurine, of Geneva, have proved, that the organ of hearing actually supplies that of sight in the bat. On completely shutting up the external auditory canals of this animal, it no longer discerns the surrounding objects; it avoids none of the obstacles in its way; but strikes against the walls, the ceiling, &c. This phenomenon, however, is not incapable of explanation. The bat cannot fly without producing a concussion in the air which immediately surrounds it; and the air thus agitated necessarily striking against the body in the line of the bat's direction, must re-act with more or less force on the ears of the animal, inform it of the proximity of the object, and dispose it to alter its course so as to avoid it.

It is undoubtedly a curious fact, that an animal should, in a manner, see by means of its ears; but our surprize will be lessened, on reflecting that there is an affinity in very many instances between the laws of sound, and those of light, and that anatomists find a considerable resemblance of structure in the organs of hearing and sight, particularly since the celebrated professor

Scarpa's

Scarpa's discovery of the aquo-membranous tubes of the ear.

§ XIX.

The history of physical science does not present us with any instance of a revolution more wonderful than that which has very lately occurred in chemistry. Reduced to a small number of facts, incoherent, and disfigured by absurd and barbarous expressions, a few years have been sufficient to change its principles, to enrich it with the most brilliant discoveries, to reform its language, and to establish a nomenclature the most intelligible and philosophical. Henceforth, chemistry, delivered from a foreign yoke, maintains a distinguished rank among the more perfect sciences, and discharges with compound interest the debts it had contracted towards medicine, physics, and the arts. It must be admitted, that chemistry has not yet acquired that degree of certainty and stability which it is capable of attaining. Some of its views are, perhaps, still defective. But, should a few errors, which time may remove, make us reject the most perfect system, taken as a whole, that has ever been conceived? Spallanzani was not much acquainted with the old chemistry; but no sooner had French genius created the new doctrine, than he embraced it with enthusiasm, and became one of its most zealous supporters. If he was not able to share in the renown of the authors of that august edifice, he was desirous, at least, of defending it against the attacks of the celebrated Gottling. It is sufficiently known that this chemist asserted, in consequence of a long series of experiments, that phosphorus does not burn but by the action of azotic gas. This was to destroy one of the grand points of the new theory, that of the combustion of bodies being exclusively affected by oxygenous gas. Spallanzani repeated the experiments of the professor of Jena*, discovered the inaccuracy of his observations, and satisfied himself.

1. That the brightness of the flame of phosphorus is always in proportion to the quantity of oxygenous gas contained in the eudiometer:—

* *Chimico esame degli sperimenti del sig. Godling*, 1796, *in* 8*vo. Modena*, &c.

I am aware that several celebrated chemists had refuted Gottling before Spallanzani; but I can assure the reader, that the latter had begun his experiments long before he knew any thing of their experiments or writings upon this subject.

 2. That

2. That agitation and change of vessel do not always revive the flame of phosphorous:—

3. That after the second combustion, the phosphorus cannot be re-kindled, even by agitation or changing the vessel:—

4. That it is probable, that in the first combustion, the phosphorous is not acted upon by every part of the vital air contained in the eudiometer; and that it comes in contact with the whole of that air by the agitation of the vessel, or, that the water furnishes, in changing the vessel, a small quantity of oxygenous gas:—

5. That, on pouring a small quantity of vital air into the eudiometer, the flame instantly reappears:—

6. That the combustion of phosphorus is always attended with an extrication of caloric and a new acid:—

7. That phosphorus, put into an atmosphere of very pure azotic, hydrogenous, or carbonic gas, does not burn at all:—

8. That, if phosphorus plunged into oxygenous gas, begins to burn and emit flame at 22 degrees

degrees only of Reaumur's thermometer; whilst it takes fire at 12°, on mixing a small quantity of azote with the oxygenous gas, and at 9°, on adding to these a little hydrogenous gas; the conclusion to be thence drawn is, that the azote and hydrogen dispose the vital air and phosphorus to combine more readily, and at a lower temperature; but, by no means, that the azotic and hydrogenous gases are the immediate cause of the combustion of phosphorus; since they are found incapable of producing that effect, when separately applied, whilst it is accomplished by the vital air alone at a high temperature:—

9. That the sun does not disengage the vital air from azotic gas, except when the experiment is made in water; and that, in this case, it is the decomposition of the water which furnishes the oxygen, &c. &c.

Rotten wood, putrescent fish, and other phosphoric substances gave the same results as phosphorus. Our author conceived, that the light emitted by glow-worms proceed from a slow combustion of pure hydrogenous gas, and sulphurated hydrogenous gas.

Of all the branches of chemistry, that with which Spallanzani was most taken was gasology. It gave me pleasure to see in his laboratory various apparatus of glass tubes filled with different gases, acting upon substances of every kind. I was present during the performance of his experiments on plants inclosed in vessels filled with air, or water, and placed in the shade, or exposed to the sun*. These experiments have thrown some doubts on a theory which has met with a very general reception. It was thought that the vegetable kingdom supplies the atmosphere with a great part of the vital air, which is consumed by animals in the act of respiration. This opinion was principally founded on the elegant researches made by Ingenhousz and Senebier, by which it appeared, that plants plunged into water, and acted upon directly by the sun's rays, exhale a great quantity of oxygenous gas. Spallanzani found that the result was similar on performing these experiments in the same manner; but it was very different when he left the plants in the shade, and in a vessel filled with atmospheric air; then, instead of augmenting the oxy-

* *Lettera al Sig. Giobert, &c. Journal de Brera, tom. III.*

genous gas, they considerably diminished it, and, by the mixture of carbon which escaped from their fibres, changed it into carbonic, acid gas. But, are not the vegetables which grow in the open air infinitely more numerous than those which live under water? Are not the greater part condemned to a perpetual shade? Do not we find many of their organs, leaves, stems, blossoms, &c. much more frequently deprived of the light, than exposed to its rays? Plants must, therefore, draw from the atmosphere a much greater quantity of oxygenous gas than they supply it with; and, from their property of changing this gas into carbonic acid gas, must contribute rather to corrupt than to purify the common air. Spallanzani does not assign any positive cause by which an equilibrium can be maintained, between the consumption and renovation of the vital air. He suggested, however, that the carbonic acid gas, continually diffused through the atmosphere, might, perhaps, be restored to its primitive elements by the agency of the waters which cover the surface of the globe; a new subject which he was the first to treat in an elaborate manner; but the results of his investigation have never been made public*.

* They will be found in the papers which he has left behind him, and they incline to the affirmative.

§ XX.

Spallanzani had made the art of conducting experiments his particular study. He had perused the works of all those authors who, from example or precept, might serve as his surest guides. Among these may be reckoned Reaumur, Redi, Malpighi, Haller and Musschenbroeck. It was, particularly from the celebrated essay of the latter "*De methodo instituendi experimenta physica*," that he learnt unerring rules, solid principles, and the necessity of varying his processes, so as to consult nature in every possible manner, and under every change of appearance. He felt the full force of that maxim of the physiologist of Berne, "*est in omnibus experimentis lex.*"

Such were the principles, and such the method of proceeding, which conducted him to the most numerous and splendid discoveries in every department of natural history, but more particularly in that which relates to the class of organized beings.

What light, in fact, has not been thrown upon the subject of organic reproductions, by his wonderful experiments upon the common earth-worm, the fresh-water worm, the tail of lizards, the head of snails, the extremities and jaws of aquatic salamanders?

By what ingenious but simple processes has he not, in a great measure, established the animality of the infusory corpuscules, which the most fascinating eloquence had been employed in reducing to the rank of inanimate beings?

Who, after Harvey and Haller, has more ably observed the numerous and obscure phænomena of the circulation of the blood, calculated its velocity and momentum, determined its causes, and ascertained the circumstances which accelerate, retard, or suspend its course, and communicate to it a retrograde, vibratory, or intermittent motion?

What performance can be more interesting, whether we consider its subject or the experiments which it relates, than that which treats of digestion? Who will, henceforth, believe in the putrefaction, fermentation, or trituration of the aliments? Who can hesitate to admit that an actual dissolution of their principles takes place, by means of the gastric juice?

If he has not thrown an equal degree of light upon the mechanism of generation*, it is because the subject is much less susceptible of elucidation. It might, indeed, be said that nature has done every thing to cover this process with an impenetrable veil. But has he not removed a part of that veil, by those singular artificial creations, which, in a manner, rendered him the rival of nature?

Spallanzani had been several years occupied in a most important work on respiration; and he was about to arrange his materials†, when death snatched

* I have remarked, in page 41, that the sagacity of animals, not even excepting the human race, is in proportion to the shortness of the neck, or rather to the relative distance of the heart from the brain. May it not be added, that the organs of generation are more or less prolific, according to their nearness to, or distance from the heart; so that the power and activity of the genital system may be regarded as in the inverse ratio of the extent and energy of the intellectual faculties?

† The fruits of so much study and labour will not be lost to the sciences. The task of digesting and presenting them to the public, is committed to the celebrated Venturi. There are some who would have wished that the editing of this posthumous work had been entrusted

to

snatched him away in the midst of an undertaking which would have greatly augmented his reputation.

Spallanzani

to Professors Scarpa, Volta, and Presciani. The first would have willingly undertaken the arrangement of the anatomical facts, the second that of the physico-chemical details, and the third that of the physiological phænomena; for this was the mode in which the author intended to distribute his materials; but the family of the deceased preferred having recourse to the friendship of the professor of Modena; and his zeal and abilities ought to inspire us with the most flattering expectations.

Modern chemistry has thrown the greatest light upon the action and use of the system of respiration. It has ascended to the source of that principle which, in subjection to the laws of vitality, maintains an equal heat in all parts of the body, under every variation of temperature. It has discovered the principles which combine with, or are separated from, the venous and arterial fluid, &c. &c. There remained, however, several desiderata with respect to this function which Spallanzani has partly supplied. He found, for instance, that a great number of animals absorb azotic gas; that this gas is decomposed in the interior of the organs, or, more properly speaking, that it becomes one of the principal elements which encreases their mass and repairs their losses:—an element which penetrates the body as much by the lungs and skin as by the chyliferous lymphatic vessels,

§ XXI.

Spallanzani, on the 3d of February, 1798, paid a visit to several of his friends, among whom I had the pleasure of being included. He went to bed in the evening rather sooner than usual, and passed a very restless night, having had scarcely any sleep. He felt an acute pain in the lower part of the abdomen, and had a retention of urine. He did not, however, send for any professional man; he was subject to these pains, which had always gone off spontaneously. About seven in the morning he suddenly lost the use of his senses.

I was soon apprized of his situation; I instantly flew to the house of the amiable and illustrious professor; I found him in bed, and affected with a stroke of apoplexy.

vessels. Though Spallanzani extended his researches to every class of Zoology, yet they were more particularly directed to the cold-blooded animals. The torpor to which they are in general subject, forms an article equally new and interesting. The systems of respiration and circulation are connected in a variety of respects, which had hitherto escaped the observation of physiologists, and the former exercises on the nervous system, a degree of influence which they were far from suspecting.

He

He had been already blooded, and enemas and other similar remedies had been administered.

Scarpa entered, accompanied by Doctor Brera. We examined the condition of the patient, directing our attention principally to the region of the abdomen, which seemed to be the original seat of the disease. It was tense, painful to the touch, and extremely sensible below the umbilicus; his urine was entirely suppressed, &c. &c. We agreed to introduce the catheter into the bladder. We found very considerable resistance to the introduction of the instrument near the neck of that organ. A great quantity of urine flowed out, which exhibited every appearance of an inflammation in the viscus which serves as its receptacle. We prescribed the medicines usually employed in such cases.

At noon, the situation of the patient was pretty much the same; towards the evening, the symptoms became very alarming; and it was feared, that the approaching night would be his last.

On the morning, however, of the 5th, Spallanzani was still in life; but his head continued affected; his eyes were insensible to the light; they could not perceive the tears shed by those around him; his ears were deaf to the plaintive cries of friendship; they could hear neither its sighs, nor its groans.—Yet his respiration was pretty free; his lungs did not appear to be affected, his pulse was frequent and small. The tension of the abdomen was somewhat relaxed; the urine was passed involuntarily; the remedies seemed to operate with greater effect; and it was conceived, that if he survived that night, he might be regarded as out of danger, or, at least as not in a desperate situation.

He survived that night; but our fears were not entirely removed; his situation, however, was by no means so critical. He frequently moved his extremities, and applied his hand to his head, as if he complained of a very acute pain in that part.

On the 7th the stupor was somewhat abated. He seemed to hear; but he answered the questions put to him, by signs only; and he had not yet recovered the use of his tongue.—He was fatigued, and in a state of profuse perspiration; he fell asleep every moment; the light was partially excluded, and the patient was kept quiet; tonics were prescribed; and he had a pretty good night.

On the 8th, he had entirely recovered the use of his senses, recognized, his friends, and conversed with them. His ideas, however, appeared very confused, and his memory extremely weak. Every thing that had happened, seemed a dream to him. He was not conscious of having suffered, nor did he now feel any pain; he merely felt a very great prostration of strength.

On the day following he attended to the offices of religion, and made some family arrangements.

A relapse, however, was still apprehended. Three days passed without any alteration for the worse.—The tempest seemed to be succeeded by a calm.—Deceitful security!—On the 12th, all the symptoms returned with such extreme violence, as to preclude every ray of hope. One half of the body was already affected with palsy. The pulse beat only at intervals; the flesh quivered to the touch.—It was the last struggle of life.—He sunk under it.—Spallanzani was now nothing more than an inanimate mass.

On opening the body, there did not appear any remarkable lesion in the head, breast, or primæ viæ. The urinary viscus was the only part that seemed to have suffered much. The whole of the internal coat was destroyed by gangrene;

and

and such was the immoderate size of the prostate gland, that it almost entirely obstructed the internal orifice of the urethra; and, thence, doubtless proceeded the resistance which was so strongly felt to the introduction of the catheter.

On the evening before Spallanzani was taken ill, I had a pretty long conversation with him relative to the affinities between apoplexy, and the periodical torpor of cold-blooded animals, which occupied his attention at that period.

§ XXII.

Few authors have, during their lives, enjoyed a celebrity so splendid and extensive, as Spallanzani. He saw his name inscribed at the head of the most esteemed performances, compared with that of the most illustrious philosophers, and every where cited as one of the most respectable authorities.

How gratifying must it be to a writer to receive from his associates such distinguished marks of regard! It makes him forget the many vexations, toils, and difficulties of every kind, which he has had to encounter. Public opinion

shields

shields him against the attacks of satire and the envious shafts of criticism. He reposes in the bosom of immortality, leaving behind him the indelible impression of a spotless life, a conduct without reproach, and a reputation acquired by rendering the most important services to science, the arts, and humanity.

Spallanzani was complimented directly by his contemporaries, with the most flattering, but justly merited eulogiums. Scarcely any man of letters, or lover of the arts, made an excursion into Italy, without paying their respects to the naturalist of Scandiano. All of them met with the most gracious reception; and all went away full of admiration at his knowledge, respect for his private virtues, and attachment for his person. Spallanzani, indeed, possessed every qualification that could tend to conciliate the esteem and friendship of those who had the happiness to know him. Kind, obliging, and affable, he had the strongest aversion to formality and constraint, and conducted the intercourse of life with the utmost openness and freedom. His conversation was always interesting and instructive. He very seldom spoke of his own productions; it was previously necessary to start some subject which required that he should allude to them;

them; and, even then, he would dexterously change the conversation, in order to spare his modesty those compliments which flatter the vanity of the greater part of writers.

The Italians were, certainly, among the first to do justice to their fellow-countryman. They had the highest opinion of his merit, and the writers of that country participated in the general admiration of Spallanzani. It was impossible, that the greater part of them should not be conscious of their inferiority; and such men as Volta, Scarpa, Moscati, Fontana, and Mascagni, could have no reason to envy his glory.

Foreign naturalists, likewise, paid him the most honourable tribute of praise. Haller dedicated to him one of the volumes of his immortal work. The founder of the most magnificent edifice that has ever been erected to the science of man, owed, doubtless, some mark of acknowledgement to one who had furnished him with such a number of materials.—"You have discovered to us," said Bonnet in a letter to him, "more truths in a few years, than whole academies have done in half a century." This observation, too, was made before Spallanzani had published

published his mineralogical productions, his chemical essays, or his various papers in natural history.

Spallanzani was intimately connected with Trembley, Saussure, Tissot, &c. Every one knows the esteem and attachment entertained for him by Senebier, the illustrious librarian of Geneva. The familiar friend of Spallanzani, and an enlightened judge of his merit, he incessantly celebrated his discoveries, extolled his talent in the experimental art, and enriched with the most intructive notes the translations which he gave of almost the whole of his works.

The Germans and English have done equal justice to the professor of Pavia. The former have confirmed by experiments almost all his discoveries; the latter, notwithstanding their prejudice against the enquiries of foreigners, have been compelled to acknowledge the importance of his observations on organic re-production, digestion, generation, &c.; and they have translated his works upon these subjects into their own language.

But France, beyond every other country, claims the merit of having assigned to this celebrated man, the honourable rank which he will occupy in the annals of history. No sooner were his works known to this nation, than we appropriated them by translations executed with elegance and fidelity. His discoveries were never mentioned but in terms of admiration, and they were adopted almost with implicit belief. His name resounded in all our schools, and it was every where heard with enthusiasm. Spallanzani was, on his part, neither unjust nor ungrateful towards the French. Impressed, on the contrary with the most lively gratitude, he took a pleasure in mentioning, both in his writings and his conversation, the many obligations which he owed to them. We have already seen what opinion he entertained of Reaumur and Buffon. The fate of Bailly, Lavoisier, Condorcet, &c. drew from him many a bitter tear. Vicq-d'Azir was, in his opinion, the only man who was capable of supplying the place of the physiologist, whose life and writings he has so well described. How frequently have I heard him speak in terms of the highest praise, of Daubenton, Lacepede, Jussieu, Bertholet, Fourcroy, Chaptal, Faujas, Guiton-Morveau, Lametherie, Dolomieu, Cuvier, Hauy, Parmentier, Vauquelin, &c. &c.! I have mentioned those only who have obtained distinction by cultivating the sciences which were the objects of his particular attention; but he was likewise well acquainted with the names and

and the productions of our principal geometricians, such as Lagrange, Laplace, Lalande, Cousin, &c. and of our most distinguished physicians, such as Barthe, Fouquét, Gouan, Portal, Bosquillon, Halle, Pinel, Dumas, Baumes, Villars, Roussel, &c.

Spallanzani rejoiced, amidst his retirement, at our first efforts to re-establish, on a long-forgotten basis, the imprescriptible rights of nature. But when he saw our enthusiasm degenerate into fury, arbitrary rule usurp the place of justice, and all France groaning under the most oppressive tyranny, he ceased, any longer, to take an active interest in our revolution, and confined himself merely to sincere and ardent wishes for our happiness.

On the re-appearance of a calm, Spallanzani, who was at too great a distance to be acquainted with our intestine divisions, imagined that we had, at length, reached the haven of security; and, when the Institute was organized, he intimated to his friends a desire of being admitted an associate. What more deserving choice could have been made by that illustrious assembly?

Spallanzani wrote only two performances in Latin; the passage which I have quoted from one of them, gives a sufficient proof of the perfection which he had attained in that language. The Italian literati rank the compositions which he published in his native tongue, till about the middle of his public life, in the number of those which furnish the most complete models of style. They possess simplicity, elegance, perspicuity, method; every thing, in a word, that belongs to the most correct and polished writer. But his countrymen are not equally favourable to the efforts of his pen in the latter period of his life. In these productions they conceive that they discover several prolixities and superfluities, a manner refined to excess, and particularly a marked affectation of giving to his phrases the turn of a language, the structure and genius of which have nothing in common with that in which he wrote.

His course of lectures embraced the three kingdoms of nature, and took two whole years in their delivery. The first year was dedicated to the natural history of animals, and the second to that of vegetables and minerals. His auditors were very numerous*; the eloquence and

* He had compiled for his own use a course of natural history, which will not be committed to the press.

Among

and fame of the professor, attracted pupils from every nation in Europe. In teaching, he did not servilely follow any plan, but by a happy union of the systematic and philosophic method, he formed for himself a new path, which opened the most extensive field to his active and fertile imagination. He recommended, however, to his pupils to consult the elements of Lescke, upon the subject of Zoology, and the works of Duhamel upon that of the physiology of plants; for his own attention was occupied with the phenomena only which related to their internal economy. Latterly, he had adopted in his course of mineralogy the division laid down by the celebrated author of the new theory of the earth.

Among the pupils whom he had at Modena or Pavia, we may distinguish the Marquis Luchesini, Ex-minister of the King of Prussia; Belloni, Bishop of Carpi; Professor Venturi, Angelo Mozzo, of Parma; Mangillii, who succeeded him as professor of natural history; I. B. Spallanzani, his nephew, and honorary professor in the University of Bologna; Salmon, Botta, and Roussel, physicians of distinction in the French army; Lagaudre, Beaufils and Revel of Cantal. I, likewise, had the advantage of attending, during eighteen months, the lectures of Spallanzani, Scarpa, Volta, and Moscati.

Spallanzani was a member, correspondent, or associate of the academies of Turin, Milan, Verona, Mantua, Bologna, Padua, Florence, Sienna, Rome, Naples, Vienna, Petersburg, Gottingen, Berlin, Stockholm, Geneva, Montpellier, Lyons, Paris, London, Madrid, &c. &c.*

* To complete the preceding sketch of the life of Spallanzani, the translator thinks it necessary to subjoin the following extracts from Senebier's eulogium upon that illustrious naturalist:

"The stature of Spallanzani was rather tall than short. He had a high forehead, lively, dark eyes, a brown complexion, and a robust frame. He had never felt, during the whole of his life, but one fit of fever; and that he caught in coming out of the mines of Schemnitz, in very cold weather. In the third year of the Republic, he was attacked with a slight retention of urine, and some symptoms of the gout, which, however, did not in the least suspend his studies." "He was adored by his relations, whose delight he always was. He never quitted them but with regret, and he always returned to them with eagerness. He had inspired them with similar tastes to his own; his brother Nicholas, a doctor of laws, assisted him when he returned to Pavia. His sister is a distinguished naturalist. She is perfectly acquainted with her brother's cabinet of natural history, knows the properties of each piece it contains, and is capable of reasoning upon them. Her mind is modelled upon that of this great man, whom it was a pleasure to her to study and imitate."

INTRODUCTION.

INTRODUCTION.

THE two first dissertations of the following work are intended, in some measure, to extend and elucidate that which I published four years ago, under the title of "The Action to the Heart on the Sanguiferous System."

Having since proposed to pursue still farther my researches, upon the circulation of the blood, I preferred, for the subject of these experiments, the water salamander. The transparency of its vessels, their accommodating flexibility, and the purple colour of the blood displayed so clearly the phenomena of that important function, that I was enabled to gather, from this small quadruped, a richer harvest of physiological facts, than perhaps any other has furnished, since the discovery of Harvey.

Farther researches have, however, convinced me, that this little animal was insufficient, fully, to answer the object I had proposed. The naturalist, as well as the philosopher, must not, it should seem, confine his attention to any single animated being; it is necessary, in order to form a comprehensive induction, that he should study and compare the habits and actions of various individuals: by this method of philosophising alone, can he ever hope to establish just theories, or extend the boundaries of the human understanding. Hence, I have been induced to subject to examination, many other animals, such as frogs, grey and green lizards, &c. &c.

The prosecution of these inquiries has so augmented my materials, that I have been under the necessity of not only revising my first essay, but of incorporating the whole into a new work, entitled, *Experiments on the Circulation of the Blood, throughout the vascular System.*

The order, and the nature of the facts have since determined me to divide this work, into two parts; one of which includes a synthetical view of the experiments, the other an analysis of their results. The same method has been pursued, in the dissertations, which relate to languid circulation, to the motion of the blood, independent of the action of the heart, and the pulsation of the arteries.

I have employed, in all my experiments, the anatomical instrument of Lyonet*, which possesses

* This instrument is, strictly speaking, nothing more than the microscope of Lewenhoeck, which is formed of a single lens; but it is much more convenient, and of far more extensive application.—

It is composed of several pieces; the largest of which is a box intended to contain the lenses and the necessary anatomical instruments. Above it is a perpendicular column of copper or brass, about nine or ten inches high, to the point of which a horizontal table, of an oval form, is attached by means of a female screw.—The two sides of this table have a circular hole, which receives the extremity of a small lever, with many spiral turns, by means of which, it may be lengthened or shortened, elevated or depressed, at pleasure.—The other extremity serves to support the lens, which the observer may direct, at his will, without being obliged to hold it with his hand upon the part which he intends to examine. The animal should be previously prepared, and attached to a small gibbet, placed upon the horizontal table. Four lenses, two of greater, and two of less magnifying powers, are necessary: the first will serve to examine the capillary vessels, the globules, &c. the second will exhibit at one view the whole object.

Although this microscope be of a very simple structure, I have, however, thought it necessary to give a delineation sesses the superior advantage of enabling us, 1, To follow the circulation of the blood, when the transparency of the vessels will allow it, from the heart, to the extremities, and from the extremities, to the heart; 2, To perform this examination, without altering the natural positions of the vessels; and 3, To make our observations with reflected light. It would be superfluous, here, to detail the advantages possessed by reflected over refracted light*. The first,

neation of it. A B represents the box half open at C B; N O the column surmounted by the horizontal table P Q; R the circular opening which receives the extremity of the lever R X Y Z, lastly Z Y the lens placed at the other extremity of the lever.

* It is almost needless to observe, that even with the microscope of Lyonet, the light by which we view the object is refracted. What, however, I understand here by refracted light, is that which is reflected upon the eye, by a mirror placed below the vessels, after having suffered a refraction across the red globules; and which in ordinary microscopes, never fails to change, more or less, the appearance of the blood. But these inconveniences are entirely obviated, by the use of Lyonet's microscope; for, although the light reflected by the globules is refracted across the coats of the vessels, it does not, I am fully convinced, produce the least change in the appearance of the circulation.

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being reflected from the surface of the objects, represents them under their true forms; the second, crossing the substance of the body, before striking the eye, not only alters the colour, but sometimes even entirely changes it. (Result XXII. Dissert. II.) These advantages will be still more evident, when we consider the mode of conducting experiments even at present; for, except in viewing the minute parts of small fishes, &c. we still follow the example of Lieberkuhn, who, after drawing out the mesentery, and securing it by means of hooks, examined, in this position, the motion of the blood, by a refracting microscope. However valuable this method may be, it is yet very far from giving us a perfect knowledge of the phænomena of the sanguiferous system; for, as the arteries and veins of the mesentery, belong to the class of middle sized vessels, it is obvious, that we must still continue ignorant of what occurs in the large and small ones*.

* The diameter of the vessels diminishing in proportion to their distance from the heart, I have divided them, for the sake of greater order and precision in my researches, into large, middle-sized, and small vessels; in the first class are included the trunk of the aorta, and vena cava; in the second, the pulmonary, the axillary, the mesenteric, &c. and in the third, the capillary branches.

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How many important facts does this ignorance prevent us ascertaining? What form do the arteries assume, at their junction, with the veins? Where, and in what manner, does this union take place? Does the impulse of the heart extend to these points of communication? With what momentum is the circulation, there, carried on? And what relation has that momentum to the motion of the blood in the large vessels? An accurate knowledge of these circumstances would lead to very important conclusions in physiology, but which we cannot hope fully to attain by the means hitherto employed.

Are we, besides, certain that the mesentery secured by hooks, continues to perform its natural functions? Should not its separation from the body of the animal, the force employed in stretching it, the spasms with which the intestines are affected, the rupture of the vessels, produced by the forceps, induce us to suspect some irregularity in the circulation?—

These doubts often presented themselves to my mind, and experience has since convinced me, that the same mesentery examined first with the microscope of Lyonet, and afterwards with the apparatus of hooks, presented phænomena essentially

essentially different. In the first case, the arterial blood circulated with equal velocity, through the trunk and the branches, (except that it moved somewhat quicker during the diastole than the systole, when the strength of the animal began to diminish), and the venous redoubled its quickness, in proportion, as it passed from the small to the middle-sized, and from the middle-sized to the larger vessels; but, in the second case, the irregularity of the circulation followed with rapidity. At one time, it was unusually slow and unequal, at another, it entirely ceased, in many of the vessels; and sometimes, it assumed a retrograde and vibratory motion. (Dissert. I. Sect. I.) A difference so remarkable between these two results, suggested to me some suspicions respecting the accuracy of the observations made upon the circulation, by former physiologists; observations established, for the most part, from the inspection of the detached mesentery.

If I may be allowed to express myself with freedom, I would say that they appear to me, in general, to have deviated from the path marked out by nature; excepting, however, in those experiments which regard the intestine motion of the blood, the rotatory motion of the globules,

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their quantity and figure, &c. which can be determined, whatever be the position of the vessels. It is moreover of importance, in some peculiar circumstances, that we should give the preference to refracted, over reflected light. (Exper. LVIII, XCIX. Dissert. I.) But when our object is to determine the laws of the circulation in the whole vascular system, to ascertain the comparative velocity of the blood in the arteries and veins, in the trunks and branches, to estimate the changes of its momentum, in proportion, as the animal becomes exhausted, and to make similar inquiries, I am convinced, as I hope the reader will be, that the mesentery, prepared after the manner of Lieberkuhn, can only partially fulfil the end we have in view.

In order accurately to observe the circulation of the blood, in the mesentery, or in any other organ, the animal must be kept immoveable, which may be effected by fixing its legs to a small gibbet. If the force, employed for this purpose, be not considerable, the blood preserves its ordinary motion; but when we stretch too much the extremities, and particularly the anterior, the vascular system, in consequence of the heart suffering a preternatural pressure, is thrown into the greatest disorder. This precaution, which

which has not hitherto been attended to, or at least not pointed out, by my predecessors, appears to me to have augmented the number of unusual appearances, which they discovered in the circulation, and which, the omission of another circumstance, equally important, seems still farther to have increased.

No physiologist, Haller excepted, has taken into account the weight of the blood; the influence of which, however, is of itself sufficient to interrupt the regularity of the circulation. (Dissert. III. Sect. II.) Unless, therefore, when we intend, as I have sometimes done, to examine its gravity alone, the vessels must be kept in a perfectly horizontal position; for if they are placed in a situation which will allow the weight of the blood to exert any influence, upon the course of the circulation, it will be impossible ever to arrive at precise conclusions.

Having not only extended my views to the whole of the vascular system, in different species of animals*, but also avoided the inconveniencies

* Besides the water salamanders, and frogs, grey and green lizards, &c. already mentioned, I have subjected to

cies attending the usual mode of conducting such researches, I have thought it incumbent upon me to publish my experiments, although I am very far from considering that the object I had in view, has been completely attained. I could have wished that my labours should not merely possess the remote and secondary utility of presenting a few detached facts, and circumstances, but that they should furnish principles, which admit of a direct and immediate application to the functions of the human body.

Analogy appears, it is true, to confirm the truth of this relation. The sanguiferous system of the animals which I examined, has the same structure as that of man: in both, the blood is composed of globules equally red; and, in both, it is propelled from the heart, to the extremities, and again returned from the extremities, to the heart. I was besides supported by the authority of Haller, who had transferred, by analogy, to the human body, a great variety of facts, drawn from a single species of animal. Notwithstand-

to examination, many other animals, such as the land salamander, the viper, and a species of water serpent: in all the results were the same.

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ing this conformity, and the example of such a respectable writer, I was unable to overcome the doubts which were suggested, even by the comparison which I instituted between cold and warm-blooded animals*: the heart of the first continues to beat during some hours after having been cut out of the body; many of them survive, some days, the destruction of this viscus. (Dissert. III. Sect. V.) They possess the faculty of living throughout the winter, and a great part of the summer, without food. The motion of the blood continues some time after they are deprived of the brain, and even the head itself. (Dissert. III. Sect. IV.) In short, the circulation is restored after having been suspended during a whole day. (Dissert. I. Sect. II.)

* We give to frogs, toads, salamanders, lizards, eels, serpents, shell-fish, &c. the name of cold-blooded animals, because this fluid in them is nearly of the same temperature as the element in which they live. We call, on the contrary, those warm-blooded animals which preserve a temperature, from about 30° to 32° of Reaumur, = to 99° of Fahrenheit.

In this class are comprehended, man, quadrupeds, birds, &c. These facts may be ascertained by placing a thermometer in the mouth or blood of these two classes of animals. In the first it remains nearly at the same degree; in the second, it rises considerably.

These singularities, which do not occur in warm-blooded animals, certainly weakened, in my apprehension, the argument drawn from analogy; the appearance of the circulation, in any one of them, might have removed every doubt, could I have observed it with the same ease, and to the same extent, as in frogs, lizards, and salamanders. Haller, who sacrificed so many animals to the promotion of science, could not discover a single red globule in any warm-blooded animal*; and the motion of the blood, observed by Cowper†, in the mesenteric vessels of a dog, a mouse, and a cat, immediately after exclusion, is insufficient to establish a general law in the vascular system.

Partaking the curiosity of this anatomist, I perceived, in reality, the course of the blood in the arteries and veins of the mesentery of some kittens; but it was only discernible for a short space of time, and in the smallest branches; even the thickness of the membranes allowed us only to see it in a very confused manner; and I should, perhaps, have still continued in the same uncer-

* Memoir upon the motion of the blood, &c. page 29, edit. of Lausanne, 1756.

† Philosophical Transactions, vol. XXIII. No. 280, anno 1702, page 1181.

tainty and ignorance, had not one of my friends, (Doctor Rezia) by a happy accident, facilitated the attainment of my wishes. Repeating, for his own information, the fine experiments of Haller, on the formation of the chick, and anxious to point out to me the gradual evolution of its organs, he presented me one dayan incubated egg, in which we evidently discerned the first rudiments of the embryo, the *punctum saliens*, and the umbilical cord, covered with a beautiful net-work of vessels. This appearance, as astonishing as new, arrested my attention. I placed the egg upon the object-stand of Lyonet's microscope; and, notwithstanding the brilliancy of the light by which it was surrounded, I beheld in so clear a manner the circulation of the blood in the arteries and veins, that, transported with joy, I conceived I might now exclaim, ἕυρηκα, ἕυρηκα!

I made this discovery in May, 1771, and I occupied myself, during the vacation, to give it all the illustration of which it was susceptible. I employed the same light as in my experiments upon cold-blooded animals. I exposed that part of the chick, which I wished to examine, to a beam of light, admitted into a darkened chamber through a hole in the window-shutter, by which means the eye, not being dazzled by any superfluous rays, could readily distinguish the hidden springs of the vascular organization. This method gave me, besides, the advantage of examining the chick at leisure; because the heat of the solar light partly supplying that which is necessary to the growth and life of the animal, the exercise of its functions continued, for a long time, unimpaired. I conducted, in the same manner, a great number of experiments upon the eggs of European and Indian fowls; and so discernible was the circulation, wherever vessels could be seen, that is, upon the umbilical cord, the membranes, and even the body of the chick, that I succeeded in repeating the principal experiments that I had made upon salamanders, frogs, &c. So complete was the identity of the phenomena, that I no longer hesitated to apply the results of the facts which I had observed, in cold-blooded animals, to all those with warm blood, and consequently to the human species. These experiments opened a road to other truths: many physiologists have accurately described the successive formation of the organs, from the moment that they fall under the cognizance of our senses, to their full growth; but no one, so far as I know, has marked the commencement, and the progress of the circulation, as the ani-

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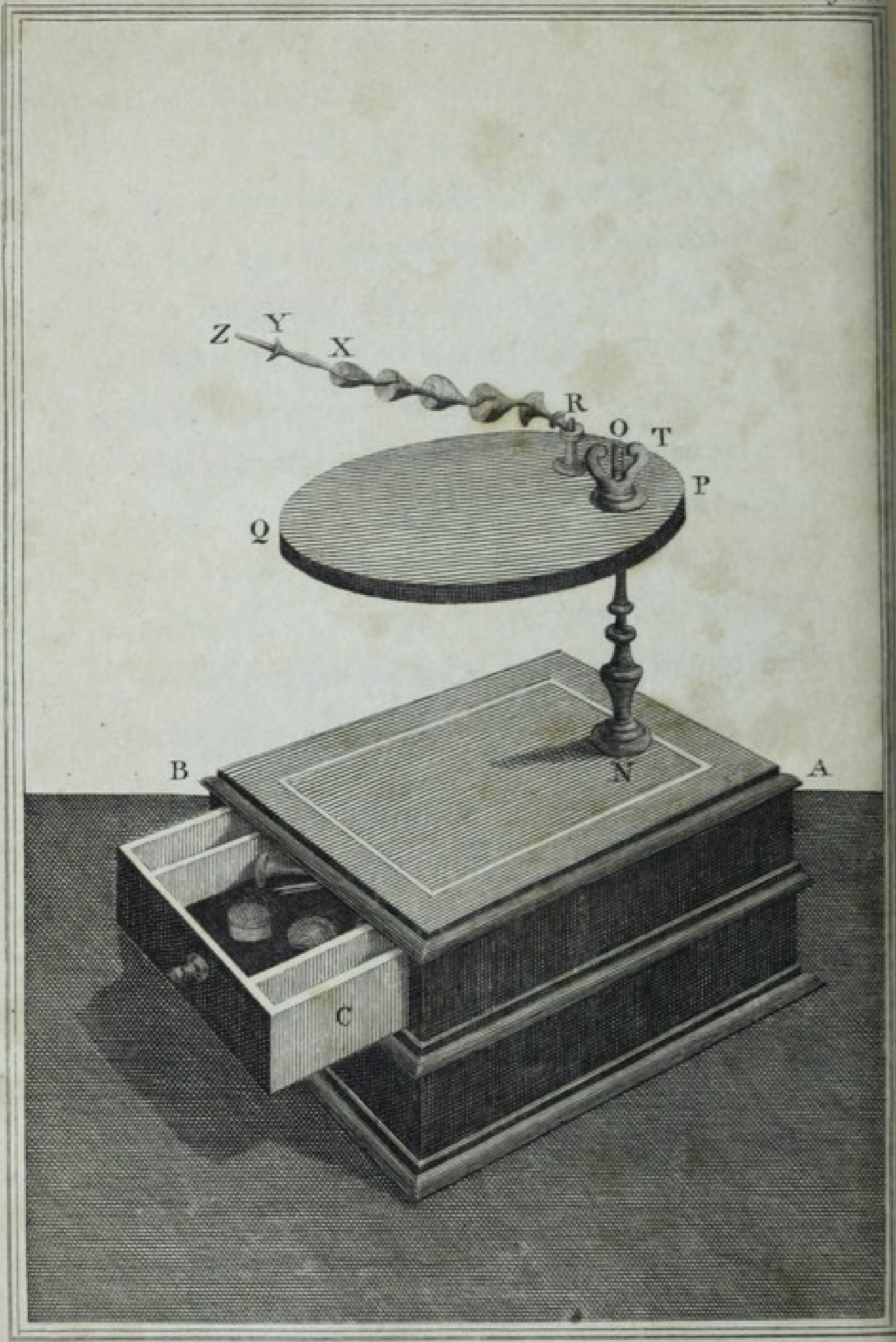
mal increases in size, as the vessels expand, and the heart acquires additional strength and energy. These important labours, which I have undertaken, and accompanied with some particulars respecting the chick, and the tadpole, have furnished truths, that appear to me well worthy the attention of the reader.

I may, perhaps, have dwelt too long upon the method which I pursued in my experiments: respecting the results, however, I shall only briefly observe, that some of them agree with those of the celebrated physiologist of Berne; but the greatest part exhibit very remarkable differences, which appear to have arisen from the greater number of animals that I have examined, and the particular method which I employed. His attention was principally, almost, indeed, exclusively, directed to frogs; but it will be obvious, that this single species is insufficient to afford us a complete knowledge of the circulation, particularly if we confine our attention, as he has done, to the vessels of the mesentery. He followed, for the most part, the method of Lieberkuhn, whilst I employed that of Lyonet, which merits, in so many respects, the preference. Far be it from me to wish to detract from the merit of this illustrious author: in pointing out the cause of the difference in our results, I have merely in view, my own justification, which the name of Haller renders so necessary. I shall conclude with a single remark. Having examined a variety of physiological questions, which had been the subject of tedious disputes among the ancients and moderns, it was easy for me to have embellished my present work with a copious and splendid display of erudition: this, however, I have avoided, that I might not unnecessarily trespass upon the patience of my readers; and because, however suitable it might be to the writer of an elaborate treatise, it could prove but little interesting to the philosophic observer.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EXPERIMENTS

UPON THE

CIRCULATION OF THE BLOOD.

DISSERTATION I.

ON THE PHÆNOMENA OF THE CIRCULATION, THROUGHOUT THE VASCULAR SYSTEM.

SYNTHETICAL VIEW OF THE EXPERIMENTS.

SECTION I.

On the phænomena of the circulation, in the large and the middle-sized arteries.

EXPERIMENT I.

I SELECTED, for the subject of my experiments, the largest salamanders that could be found in our ditches. They are about four inches in length; and have the breast and belly streaked with a bright yellow, interspersed with blackish spots, which extend to the back, where they asssume a lighter shade.

To preserve the animal in a fixed posture, I fastened the four legs to a small gibbet, and afterwards opened the integuments from the tail to the head, which I folded back, and kept extended by means of pins. The cold-blooded animals were prepared in a similar manner; after which it was easy to examine, with a lens, the ovaria, the fallopian tubes, the vasa deferentia, the gall-bladder, the intestines, the mesentery, the lungs, the liver, &c. It was necessary, however, previously to remove, in the salamander, a thin membrane, which, after the manner of the peritoneum, covers, and is reflected over these different parts. The ventricle, the auricle, (for the heart of salamanders, and other cold-blooded animals, has only one ventricle and one auricle) and the aorta are, moreover, invested with a second tunic, which is, perhaps, only a re-duplication of the common integument.

The heart of the salamander, inclosed within its tunics, (the inmost of which may be said to constitute the proper substance of the *pericardium,*) was, by its alternate motion, the first organ that attracted my attention. This viscus, during its systole, shortened, and receded a little from the pericardium; whilst during its diastole, it became elongated, and raised up this membrane, whose resistance caused the heart to bend itself towards the auricle, which dilated and contracted alternately. But such was the rapid

action

action of the ventricle, and auricle, that I could not ascertain their reciprocal pulsations, although the transparency of the coats allowed me to see these two organs.

In endeavouring to separate the pericardium, the auricle was accidentally torn, so that the blood gushed out, and prevented me from continuing my examination.

EXPERIMENT II.

On a salamander, two grey lizards, two green lizards, and two green frogs.

I was more fortunate in this experiment, in which I succeeded in removing the pericardium, without in the least injuring either the heart or aorta. I have ascertained (this circumstance having frequently occurred in the course of my experiments) that, by exposing the heart, we allow the liquor pericardii to escape; a fluid, which is very limpid, and found in a greater or less quantity, in every salamander. The heart, deprived of its membranous capsules, rose in the diastole, much more than it sunk in the systole. To discover the precise degree of this difference, I took an iron wire, which I suspended perpendicularly to the horizon, upon the apex of the heart, so that this muscle could, in its greatest

elevation,

elevation, scarcely touch it: having then measured the distance of the iron wire from the apex of the heart, I found that it equalled about one line*. The heart of green frogs, of grey and green lizards, displayed an action similar to that of the salamander; shortening in the systole, and lengthening in the diastole, the opening of the pericardium allowed the water which it contained to escape.

EXPERIMENT III.

On several salamanders, grey and green lizards.

I endeavoured to follow with my eye the course of the blood from the vena cava into the

* It was, at one period, a subject of controversy, whether the heart shortens or elongates in the time of its systole: an inspection, however, of the hearts of frogs and other animals, either in the body or when separated from it, must convince any observer, that our author is perfectly correct in affirming, that this viscus is lessened, in all its dimensions, on each contraction; and that it becomes distended and elongated during the period of dilatation. From a comparison of the experiments made by Drs. Hales and Langrish, it appears, that the capacity of the left ventricle of an ox's heart, at the termination of each systole, is to its capacity when fully dilated, nearly as 1 to 2½. Vid. Hales's Statical Essays, vol. II. Langrish's Cronean Lectures, No. 147. *R. H.*

auricle, from the auricle into the ventricle, and from the ventricle into the aorta: but the pulsations were at first so frequent and so rapid that I could distinguish nothing. Having waited some moments, I observed the following phænomena: when the blood flowed from the vena cava into the auricle, this dilated, and was overcast with a deep red, by the numerous globules which entered it, under the form of a small purple cloud, much more perceptible in the auricle of the salamander than in that of grey or green lizards. The blood afterwards passed into the ventricle, which became distended, whilst the auricle was emptying itself; after which, it was expelled by the contraction of the heart into the great trunk of the aorta. It was, however, necessary, in order accurately to observe the course of the circulation, previously to exhaust the vigour of the animal. We then saw, without the help of a microscope, that the auricle of the salamander continued to swell during the time that the vena cava was contracting, and that its systole was performed more quickly than its diastole.

The present opportunity seemed favourable to examine if the heart emptied itself entirely during the systole. Of this circumstance, however,

ever, we could not be certain from a mere inspection of that viscus, owing to the thickness of its coats, which allowed us only to conjecture that it became empty, as often as it lost that beautiful red colour which it assumed during the diastole. In the grey and green lizards, the heart became extremely pale during each contraction, as it did, also, in that of salamanders and green frogs, enfeebled by a long want of sustenance; but this organ preserved a tint somewhat red, if the mass of blood had experienced no diminution.

EXPERIMENT IV.

I concluded, therefore, that the heart of salamanders and of green frogs in a healthy state, retained during each systole a small quantity of blood. Wishing, however, still more to convince myself of this fact, I opened the apex of the heart in four salamanders, and in four green frogs, towards the end of its contraction; from this opening a considerable quantity of blood flowed out; but less than during the subsequent diastole. From the heart of those salamanders, on the contrary, which had been rendered extremely pale, hardly a few drops were effused.

EXPERIMENT

EXPERIMENT V*.

The aorta resembled, near the heart, a small intestine, which, after making a kind of curvature, directed its course towards the head, where it formed a bulb, whose size was sometimes equal, and sometimes inferior to that of the ventricle. At every systole of the heart, the blood flowed into the great canal of the aorta, in a manner so apparent, that if merely a ray of light was made to fall upon it, in a darkened chamber, the use of a microscope became unnecessary. This vessel, however, was not instantaneously filled; the blood entered it, under the form of a small column perceptible by the eye, whilst the artery dilated, and assumed a deep red colour.

EXPERIMENT VI.

The results were the same as in the former experiments, excepting only a new phænomenon, which I have had occasion often to observe, in the prosecution of my researches. Although the salamander had been prepared, for a little while, and the blood circulated with rapidity, it how-

* In the experiments where the animals are not named, one or more salamanders must be understood.

ever stopt all at once in the vena cava, in the auricle, the ventricle, and the aorta. Having discovered that this remora arose from the heart itself, which, during four minutes, had ceased to beat, I restored the action of this organ, and the blood immediately resumed its former course.

EXPERIMENT VII.

After the animal had been fixed upon the gibbet for an hour and a half, the pulsations of the heart became less frequent, and the aorta appeared to be completely empty, towards the end of its contractions: at least, it lost, during the systole, all the redness which it had acquired during its dilatation. To remove, however, all ambiguity, I made a tranverse incision into the contracted vessel, from which not a drop of blood was effused; but, during the following diastole, a very considerable quantity flowed out.

EXPERIMENT VIII.

I repeated the former experiment upon several salamanders that had been fixed for some time upon the gibbet: the result was the same. If I opened on the contrary the aorta, immediately after the preparation of the animal, a small quantity of blood always flowed out.

EXPERIMENT IX.

I then suspected that the difference of these results arose from the different degrees of strength of the animal; that is to say, during a state of vigour, the aorta retained a small quantity of blood, but became entirely empty, when the salamander began to grow feeble. Having frequently experienced the happiest effects from refracted light upon some other vessels, I was led to direct the solar rays, by means of a lens, upon the aorta, which enabled me to ascertain that, whilst the circulation continued unimpaired, the aorta retained, during the systole, a small quantity of blood. I likewise discovered, that this fluid then ceased to circulate, and recovered its motion only during the following diastole. The blood experienced, therefore, a retardation in the aorta, more or less considerable, according to the longer or shorter interval between the end of the systole, and the commencement of the diastole, of this vessel.

EXPERIMENT X.

On three salamanders.

I repeated, with equal success, the two foregoing experiments.

EXPERIMENT

EXPERIMENT XI.

I continued my examination of the aorta. From its bulb originated four trunks, two of which, immediately before reaching the beginning of the spine, united into a single canal, which descended, without any covering, along the back. This canal, which we shall call *aorta descendens,* was concealed from the sight, near the origin of the tail. The diameter of the descending aorta was evidently more considerable at its rise than its termination. The portions, however, situated between the branches which it produced, were of a size nearly alike, and rather of a cylindrical, than conical figure.

EXPERIMENT XII.

On several salamanders.

The pulsations of the aorta were very considerable, and, at every systole, it remained full of blood, which ceased to circulate in the two superior thirds of this vessel, at the moment when it contracted, that is, during the dilatation of the heart: but, in the inferior portion of the aorta, this fluid experienced a less considerable remora, so that, having arrived at the extremity of the tail, it moved, merely with greater languor,

guor, during the diastole, than the systole of the heart.

EXPERIMENT XIII.

On two green lizards.

The blood circulated, with considerable rapidity, in the descending aorta, and in such a manner, that although it stopped for a moment in one part of this vessel, it presented in the other an equal and uniform course, nearly as we have explained in the last experiment.

EXPERIMENT XIV.

On three grey lizards.

The circulation was very evident in the descending aorta. The blood circulated irregularly, in the superior half of this vessel; but uniformly, in the portion near the tail; with this difference, however, that its course was somewhat more rapid, during the contraction of the heart.

The aorta, in grey and green lizards, had a pulsatory motion, and retained, during its systole, a very considerable portion of blood.

EXPERIMENT XV.

On several land and water frogs.

The results were the same as in experiments XII. and XIV. The circulation was discernible, only, in the descending aorta of very small frogs: the large ones serving merely the purpose of enabling us more accurately to estimate the number and strength of the pulsations.

EXPERIMENT XVI.

On several salamanders.

I endeavoured to discover whether the pulsation of the descending aorta took place in an instantaneous or gradual manner: that is, if, during the systole of the heart, this artery was dilated by degrees through all its course, so that the eye could follow, thus to speak, the successive degrees of that dilatation: but, it appeared, that at the moment when the heart contracted, the aorta swelled up at once from its origin to its termination.

EXPERIMENT XVII.

On two grey lizards, two green lizards, and two frogs.

The aorta underwent, at once, an equal dilatation, through all its extent.

EXPERIMENT XVIII.

From the descending aorta, originate several middle sized arteries, the most remarkable of which are, the pulmonary and mesenteric. The lungs of the salamander are composed of two small sacs, or membranous vesicles, stretched along the abdomen, and usually full of air. Their length is about an inch, and the animal can fill or empty them, at will, according to the quantity of air which it inspires, or expires. Each of these sacs receives an arterial trunk, which is distributed in a right line from the base to the top of this viscus. This trunk furnishes, in its passage, a great many branches, making, for the most part, either an acute or a right angle with the artery; which, considered through all its extent, presents a cylindrical form. The portions, however, which are comprised between the interstices of the branches, have an unequal diameter.

This trunk exhibited no sign of pulsation. The blood moved with velocity, in the superior portion of the lungs; but it stagnated in the inferior third of the artery and its ramifications.

An hour afterwards, the circulation ceased in the half of the lungs, and the effects of the contraction and dilatation of the heart, became more evident.

An hour and a half later, the course of the blood was only visible in the seventh part of the lungs. It is worthy of remark, that as much as it advanced during the contraction of the heart, so much did it move backwards during its dilatation. The lungs, however, had already collapsed; many of the branches were empty, and others of them contained only a very small quantity of blood.

EXPERIMENT XIX.

The blood of the pulmonary artery circulated with uniform velocity, unless in the most distant ramifications, where its motion became less rapid. This vessel had no evident pulsation, and the blood maintained, on entering the branches, its usual quickness.

The other results were the same as in the last experiment.

EXPERIMENT XX.

The pulmonary artery displayed three dilatations, in which the blood became more red and less rapid: but no sooner did it emerge, than it recovered its original motion and colour. Upon the lungs collapsing, the membranes were turned in, so as to conceal from the sight the greatest number of its vessels: the arteries, however, were yet visible, but the blood no longer circulated with its accustomed velocity.

EXPERIMENT XXI.

On several salamanders and frogs.

Having proposed to enquire, whether the blood lost its velocity in flowing from the trunks of the pulmonary artery into the branches, I discovered that it was uniformly the same, whatever might be the angle formed by these vessels. In proporton as this fluid advanced into the smallest ramifications, its motion abated by degrees; so that, were we to compare the velocity of the circulation in the trunk with that in its ultimate branches, the difference would be as three to one.

In frogs, each lobe of the lungs is provided with two arteries, whose pulsations were scarcely discernible; and they retained, on contracting, a very considerable quantity of blood, the motion of which was more rapid during the systole, than the diastole of the heart; and equalled that in the pulmonary artery of salamanders. No sensible inequality was observable, excepting in the most extreme ramifications, between the circulation in the trunk and branches, although these, for the most part, made with the former, an acute or right angle.

The blood of the frogs was paler than that of the salamanders, although they had been both prepared at the same time.

EXPERIMENT XXII.

Notwithstanding the animal had been recently prepared, the blood oscillated in the two pulmonary arteries. Although unable, at first, to explain the cause of such an irregularity, I afterwards discovered that it proceeded from the anterior extremities having been so much drawn asunder, as to impede the free motion of the heart. Having diminished the extension of the extremities, this viscus resumed its original action, and to the oscillation succeeded a very rapid motion.

EXPERIMENT XXIII.

I stretched, considerably the extremities of the salamander, to satisfy myself if the oscillation would

would re-commence: it, in fact, re-appeared, and continued until the extension was removed, when the blood resumed its original course.

EXPERIMENT XXIV.

On four salamanders.

Having remarked how essential the freedom of the heart's action was to the equality of the circulation, I took care in the present, as well as in the subsequent experiments, not to stretch, in particular, too much the anterior extremities. In that case, the pulmonary artery displayed not the smallest sign of any unequal or oscillatory motion. When, however, the strength of the animal had been somewhat reduced, the circulation became less rapid during the diastole; sometimes, even, it was succeeded by an oscillatory motion which was propagated, by degrees, from the smallest ramifications to the trunks themselves.

EXPERIMENT XXV.

On several salamanders and land-frogs

I have mentioned in the third and fourth experiments, that the heart of salamanders and land-frogs did not become completely empty during the systole. Having discovered that the free action of this organ was necessary to the regularity of the circulation, I conjectured that this residue of blood proceeded, perhaps, from the want of a sufficient contraction of the heart, to expel it from its cavity: but this experiment has convinced me, that the ventricle retains always a certain quantity of globules, although it has not experienced the least impediment to its action.

EXPERIMENT XXVI.

On three frogs, two grey lizards, two green lizards, and two salamanders.

The circulation is often disordered in frogs by the pressure which the lungs sustain on opening the abdomen. Being then extremely dilated, they escape through that place where they meet with the least resistance; that is, by the opening which we have made, so that, if it be not sufficiently large, the lungs experience a strangulation, which suspends or retards the motion of the blood: but this obstacle is no sooner removed, than it resumes its original velocity.

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I opened the lungs without injuring any trunk, but they were so collapsed that I could neither discover blood nor vessels.

The two arteries which are distributed to the lungs of grey and green lizards, displayed a sensible pulsation throughout their course; the thickness of the membranes, however, permitted us only to observe the circulation in the trunks. The blood was expelled *per saltum*, much more rapidly during the systole than the diastole of the heart. The large vessels remained full of blood.

Upon making a slight incision into the lungs of the salamanders, the motion of the blood became slower, but did not entirely cease.

EXPERIMENT XXVII.

The mesentery stretched with hooks.

I turned my attention to an artery, in which the blood experienced a retardation only during the diastole of the heart. This artery is divided into five branches: the first displayed a dilatation, in which the blood became of a deeper red, and diminished in quickness; it oscillated in the second, and preserved an uniform course in the three

three others; in two of which, however, its momentum was more rapid than in the trunk. In about thirteen minutes, the oscillation was propagated to all the branches, and five minutes afterwards, it reached the arterial trunk. This oscillatory motion, did not, however, continue either in the trunk or branches above three minutes; after which, the blood resumed its usual velocity for a quarter of an hour, and then re-commenced its former oscillation. A large artery, which was distributed to another portion of the mesentery, gave rise to two others, the first of which was subdivided into two, the second into five branches; all diverging at acute angles. In some of these the blood stagnated, whilst it circulated, or oscillated in others.

Observing an artery run in contact with a vein, in which the blood circulated with extreme languor, I conceived it a favourable opportunity to ascertain if this artery possessed any pulsatory motion; as, in that case, some alteration must have been produced in the circulation of the venous fluid; but I was unable to perceive that it had experienced the least change.

EXPERIMENT

EXPERIMENT XXVIII.

In preparing the salamander, a part of the mesentery was torn; enough of it, however, remained uninjured to display a singular phænomenon. An artery gave rise to three branches of an equal size, in which the blood was distributed very unequally. The first branch received less than the second, and the third much more than the two others. The colour of the blood was in a direct ratio to its quantity, that is, pale in the vessel which contained least; red and purple in that which had the most. The globules, in the two first branches, were not in contact with each other, and appeared to float in an invisible fluid: they were yellowish, and of a round figure. Upon repeating this experiment with reflected light, the yellowness of the globules was changed into red, deeper in proportion as their number was considerable.

EXPERIMENT XXIX.

The blood circulated with rapidity in two arteries, and two veins, which formed by their intermixture with each other on the mesentery, distinct rhomboidal figures. No disorder occurred in the motion of the blood in the veins, at at their union with the arteries: an evident proof that these have no pulsation.

EXPERIMENT XXX.

The mesentery stretched with hooks.

I observed, during two hours, the circulation of the blood in an artery which supplied the mesentery with several branches. The following were the principal results of this experiment. During seven times did the blood in the artery and its branches alternately oscillate, and recover the velocity which it possessed, previously to the preparation of the salamander. The oscillation, which imitated the vibration of a pendulum, began in the branches, and was afterwards propagated to the trunk. The retrograde motion of the blood, during the diastole, was equal to its progress during the systole.

EXPERIMENT XXXI.

The mesenteric vessels of a frog, enfeebled by long abstinence, appeared, by refracted light, of many different colours. The globules and coats of the smallest vessels, were of a shining white, the middle-sized had a yellowish tint, the large ones a yellow colour, which assumed, in

proportion

proportion as the vessels augmented in diameter, a reddish shade, and presented to our view the deepest red in the arterial and venous trunks.

This experiment, repeated with reflected light, gave very different results. The red was the only colour which predominated in all the mesenteric vessels; somewhat, however, paler in the small, than the large ones.

EXPERIMENT XXXII.

Upon several frogs and salamanders.

In order to ascertain if these illusions proceeded from the employment of refracted light, I repeated the foregoing experiment upon several frogs which had been kept without food for a longer or shorter period. The different tints, already mentioned, re-appeared when the examination was made with refracted light; the red, however, was only visible in the largest vessels. These shades disappeared when the light was reflected, with this difference, that the red colour was less brilliant in the mesentery of those frogs which had suffered from a long deprivation of food. Some of the animals had been reduced to that degree, that scarcely any blood

blood remained in the vessels; and the intestines were so much contracted, that the mesentery could not be displayed.

I examined, with these two kinds of light, the mesentery of the salamanders; but as their blood presented a deep red colour for a much longer time than that of frogs, it was necessary to deprive them altogether of food for some months, in order to obtain, by refracted light, that mixture of colours which appeared in the mesentery of frogs.

EXPERIMENT XXXIII.

On three salamanders.

I next examined the figure of the mesenteric arteries, and the ratio which subsists between the diameter of the trunk, and that of the branches. The arteries, considered in all their extent, were conical, excepting only those portions situated between the branches, which had a cylindrical form. The capacity of the branches always exceeded that of the trunk from which they took their rise: this is, indeed, an universal law throughout the arterial system.

EXPERIMENT

EXPERIMENT XXXIV.

The mesentery stretched with hooks.

The blood oscillated in some of the mesenteric arteries; in others of them, its course was uniform, but extremely languid. These vessels were divided into many branches; but the blood, in passing from one to another, experienced no retardation. The fluid contained in each artery, was divided into several columns, proportioned to the diameter of its ramifications. The globules, which on account of their small number, could be viewed singly, exhibited no rotatory motion, but followed in an uniform progression, the course of the blood.

EXPERIMENT XXXV.

The mesentery stretched with hooks.

A mesenteric artery presented towards the middle of its course, a contraction, in which the blood circulated with augmented velocity. In order to ascertain if this increased momentum was in consequence of that contraction, I divided the mesentery, to which several vessels were attached. Upon the tension being thus removed, these vessels contracted, and the diameter, in that portion of them opposite the incision, was considerably lessened. The blood, as I had conjectured, circulated in this part of the artery, with increased rapidity; but scarcely had it emerged until it resumed its original motion.

I repeated this experiment upon several other arteries, with an uniform result.

EXPERIMENT XXXVI.

The mesentery stretched with hooks.

Although I began this experiment immediately after the preparation of the salamander, the blood, nevertheless, oscillated in the arterial vessels of the mesentery. One artery, after having crossed in a right line a considerable portion of this membrane, formed several windings, resembling five S: upon reaching the intestine, it divided into two branches, one of which made seven, and the other nine curvatures. During the contraction of the heart, the blood recovered its usual course in the artery and its tortuous ramifications; which appeared not in the least to diminish its original momentum. This fluid moved in a retrograde direction, during the systole, without, however, losing any part of its velocity, in traversing the numerous curves, and re-duplications of these vessels. The oscillatory motion disappeared, after the lapse of seventeen minutes, and the blood resumed its original motion, as in Experiment XXX.; it ceased not, however, to circulate with equal rapidity in the crooked and straight portions of the artery.

EXPERIMENT XXXVII.

Two arteries partly straight, and partly tortuous, formed upon the mesentery different angles. The one, after having run in a right line, through the whole extent of this membrane, made four curvatures, two of which crept upon the edges of the mesentery, and the other two upon the coats of the intestines. The other artery, after dividing into two branches, exhibited various flexures and circumvolutions. The blood, however, experienced no retardation, but circulated with equal rapidity throughout all these different ramifications.

EXPERIMENT XXXVIII.

I folded back the mesentery in such a manner, that those arteries which were naturally straight, formed different curves, in order to ascertain if this method would diminish the rapidity of the blood, but it produced not the smallest alteration in its original motion.

EXPERIMENT XXXIX.

The mesentery stretched with hooks.

The blood oscillated in several mesenteric arteries, circulated in some, and stagnated in others. The natural curvature of the vessels produced no alteration in these several motions. In stretching the mesentery, a vessel was ruptured, from which a few drops of blood escaped, and there was formed, at intervals, in the injured vessel, a bubble of air which followed the course of the red globules towards the intestines.

EXPERIMENT XL.

On three salamanders.

The blood circulated with extreme velocity, and its course was much more rapid in the pulmonary, than in the mesenteric arteries; the difference might be about one quarter. There issued, from a dilatation in the trunk of the pulmonary

monary artery, several air bubbles, which arrived at the extremity of the lungs with the blood.

EXPERIMENT XLI.

On three salamanders.

Four arteries crept along the surface of the palate, and after a considerable course disappeared: two of them sunk into the cranium at the distance of three quarters of a line from the internal globe of the eye, the other two into the muscular portions of these organs. The circulation of the blood was carried on in these four vessels, with the same velocity as in the pulmonary arteries, but continued for a much longer space of time.

EXPERIMENT XLII.

The blood circulated with equal rapidity in the mesenteric trunk, and its different ramifications: it only began after seventeen minutes to experience the acceleration produced by the contraction of the heart; a few pulsations were observable in the trunk.

The salamander was of a middle size.

EXPERIMENT XLIII.

The arterial mesenteric trunk of a much larger salamander during the systole and diastole of the heart, experienced an alternate dilatation and contraction, which were extended even to the origin of the mesenteric arteries.

EXPERIMENT XLIV.

Having been unable, notwithstanding the rapidity of the circulation, to mark any pulsation in the axillary arteries of a large salamander, I could not hope to discover that action in the very small animals of the same species. It occurred, however, contrary to my expectations, in the middle sized arteries of another salamander.

EXPERIMENT XLV.

On two grey and two green lizards.

Very frequent pulsations occurred in the mesenteric trunk, its branches, and their subdivisions; and were evident, at the same time, in the aorta, and the arteries, which last remained

remained full of blood during the contraction of the heart. These pulsations, however, became less sensible in proportion as the diameter of the vessels decreased.

During the systole, the circulation increased in the mesenteric trunk, and the blood flowed in the other arteries with an equal and uniform velocity: in proportion, however, as the animal became enfeebled, the former motion of the blood appeared to abate during the diastole of the heart.

EXPERIMENT XLVI.

I endeavoured to discover if the globules experienced any intestine or rotatory motion in passing the angles and curvatures of the two mesenteric arteries, but, after the strictest attention, I could distinguish neither the one nor the other. It appeared, however, that in striking against these angles and curvatures, the globules, after two or three revolutions, followed the course of the circulation without afterwards exhibiting any kind of whirling motion.

EXPERIMENT XLVII.

As the blood circulated during the former experiment with extreme languor it seemed possible, that had its course, and consequently that of the globules been more rapid, the result might have been different. The same experiment, however, repeated upon this supposition presented nothing dissimilar.

EXPERIMENT XLVIII.

On six grey and five green lizards.

The sinuosities and angles of the arteries produced no retardation in the circulation: nor did the globules experience any intestine or rotatory motion.

SECTION II.

On the phænomena of the circulation in the small arteries and veins.

EXPERIMENT XLIX.

The gall-bladder, in the water salamander, has some resemblance to a small egg whose apex rests upon the liver. It is usually filled with bile, and its light green colour proves extremely favourable to the examination of the blood vessels, which consists of two arteries and

and three veins. One of these arteries crosses, in a right line, the whole extent of the bladder; the other, a little smaller, divides into two branches; the first taking a retrograde course, the second proceeding to the extremity of this receptacle. These two vessels give origin to several branches, which are divided or subdivided into innumerable ramifications. In pursuing this maze of vessels the eye is at first distracted, but, in a short time, it can distinguish the beginning of three veins whose diameter augments in proportion as they proceed from the base to the apex of the gall-bladder. The action of the arteries, although extremely rapid, did not, however, exceed that of the veins, excepting only some branches into which the blood flowed with unusual slowness. The globules, which moved singly, appeared of a red colour, not only when viewed with reflected but even with refracted light, that is, by a reflecting mirror placed under the gall-bladder, so that the rays, being refracted across its thick green sides, represented the globules in their natural state. No difference was perceptible between the circulation in these five vessels and in the larger arteries.

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I made a small opening into the gall-bladder, from which all the bile having escaped, the motion of the blood immediately ceased.

EXPERIMENT L.

On four salamanders.

The result was the same as in the last experiment, excepting only that upon the flowing out of the bile, the blood did not cease to circulate in the vessels of the gall-bladder.

EXPERIMENT LI.

On several salamanders.

A small artery which had formed on the mesentery eleven or twelve curvatures, gave rise to several branches ; one of these extended to the intestines, where it subdivided into many ramifications of a capacity sufficient to contain a single globule. From these ramifications, in turning back towards the mesentery, proceeded a vein which anastomosed with another much larger destined to carry the refluent blood to the heart.

These

These curvatures did not diminish the momentum of the blood, excepting only that its course was less rapid in the middle sized vessels, and that in the venous branch, which proceeded from the artery, it moved with the same velocity as in the artery itself. It circulated, indeed, slower in the most extreme ramifications.

Another artery, which presented in its course no curve whatever, had scarcely reached the stomach, before separating into five small branches which formed upon the external coat of this viscus a beautiful net-work of vessels, in which the globules circulated with very great rapidity. This net-work was evidently produced by the continuation of the extreme arterial ramifications into corresponding veins; for in directing the microscope upon that part of the stomach opposite the mesentery, it was apparent, that from this intermixture of small vessels several veins originated, whose union formed the branch of a mesenteric vein in which the blood circulated with greater rapidity than in its ramifications.

EXPERIMENT LII.

The teguments of the neck covered various muscles, on which crept a prodigious number of small arteries, proceeding in a right line to the jaws, where they divided into a great number of branches which took a retrograde direction, and passed into continuous veins whose direction was parallel to that of the arteries. Thus the muscles presented a double order of vessels, one set of which carried the blood upwards, the other downwards; but in both, the circulation was slower than in the middle sized vessels of the mesentery. It seemed worthy of remark, that each vein derived its origin from several arterial ramifications.

EXPERIMENT LIII.

The two cartilagious epiphyses of the bone with which the humerus was articulated, served as a fixed point to two series of arterial vessels, extending over the one half of these cartilages, where they formed a vein which crept upon their inferior border. The greatest part of these arterial branches anastomosed immediately with the vein; some others terminated, after dividing into several ramifications. The momentum of the blood increased in this vein in proportion to the augmentation of its capacity, and was more rapid than in the small arteries. These vessels could not be examined in their natural situation: hence, the circulation in them ceased very suddenly.

EXPERIMENT LIV.

The variety of vessels remarked in Experiment LII. gave rise to a very important and delicate observation. One of the largest arteries which crept upon the muscular fibres, very soon divided into two branches: one of which continued its course towards the head, the other changed into a vein, and descended towards the breast. During every contraction of the heart, the blood augmented in velocity, not only throughout the artery but even in a portion of the vein itself; with this difference, however, that the acceleration diminished in the systole, in proportion as the blood approached the heart. I observed this phænomenon more than a quarter of an hour; unwilling that my readers should be led into an error which I myself might have committed *.

EXPERIMENT

* The reader must not confound these two expressions, *acceleration of the venous blood*, and *acceleration of the venous blood during the systole of the heart*. The first is intended to express a constant acceleration independent of the contraction or dilatation of the heart, which

EXPERIMENT LV.

A vein which anastomosed with that of the spleen, originated from two arterial ramifications proceeding from the stomach and mesentery. The salamander not having been in the smallest degree enfeebled, the blood circulated in these vessels with the same rapidity as in the pulmonary artery.

EXPERIMENT LVI.

The middle sized arteries of the velum palati (Exper. XLI.) were interwoven with a great variety of small arterial and venous vessels of a capacity sufficient to contain only a single series of globules, which appeared of a reddish colour, but became darker in those branches where they were accumulated in a greater quantity. Although the globules were at a considerable dis-

which was more evident, and encreased in proportion as the veins became larger, and approached the principal trunks, as may be deduced from Experiments XLIX. LI. LIII. &c. &c. The second species of acceleration was, in a strict sense, owing to the systole of the heart, and continued only during the time of its contraction.

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tance from each other, they circulated with very great rapidity ; yet not with the same velocity as in a capillary vein situated in the middle of the palate, which derived its origin and principal enlargement from the small arterial vessels of which we have already spoken.

A distinguishing feature of the arterial and venous system was, that the blood, notwithstanding the extreme smallness of the vessels, circulated during several hours with the greatest rapidity ; it afterwards abated, and the action of the heart did not extend beyond the arterial ramifications.

EXPERIMENT LVII.

A net-work of small arteries, implanted in the coats of the intestines, appeared to terminate in several veins which ran along their sides.

EXPERIMENT LVIII.

I endeavoured to discover, 1st, whether the vessels which admitted only a single globule at a time, were of a cylindrical figure ; 2d, the relation which subsisted between the size of the globule and the diameter of the vessel ; but I was

was unable to succeed in these enquiries with reflected light, and found it essential that the object to be examined should be strongly illuminated underneath; even in this manner, however, some difficulties were to be overcome, although one of the most transparent parts of the mesentery had been selected for examination. It seemed, as if the globules circulated without being inclosed, in an actual canal. I perceived that the sides of several vessels were of a cylindrical form; that their coats were composed of two thin and somewhat obscure laminæ, whose interior appeared of a shining white. The globules circulated at a given distance from each other, and without coming into contact with the sides of the vessels to which, however, they approached very near: the difference between the size of the globules and the capacity of the vessel was consequently very small.

EXPERIMENT LIX.

On two salamanders.

In this the result was the same as in the preceding experiment.

EXPERIMENT

EXPERIMENT LX.

I disposed in the form of an arch a small mesenteric vessel in which the globules circulated without actual contact, and with an uniform quickness. After three quarters of an hour, an oscillatory motion commenced, and the globules moved backwards and forwards, but without striking against each other.

EXPERIMENT LXI.

The blood circulated with its usual velocity in an intestinal vein, although it had twenty-five curvatures.

EXPERIMENT LXII.

Salamanders have two ovaries, as well as two oviducts, which are extended under the form of two whitish cords from the anterior extremities to the beginning of the tail ; their brightness permitted us to see the various convolutions of the small vessels, the greatest part of which appeared to emerge from the interior of the oviducts, and many others to sink into them. The distribution of some veins may be compared to a shrub, a shrub, with its trunk, branches, and ramifications; the circulation, however, was carried on with greater rapidity in the trunk than in its ramifications.

EXPERIMENT LXIII.

The brilliant yellow of the belly and breast of the salamander, (Exp. I.) presented, at first sight, a confused mass of corpuscules: but, on examining them with greater attention, we soon discovered an intermixture of arterial and venous vessels, not more different in their form than in their size and length, in which the blood appeared to circulate with the same quickness as in the pulmonary arteries.

The velocity of the circulation was augmented by the union of several branches into a single trunk. The yellowness of the breast and the belly diminished in several places the redness of the blood, which approached more to a yellow than a red in the branches containing a single globule; it was somewhat yellowish in the middle sized vessels, and of a deep red in those of a diameter more considerable.

EXPERIMENT

EXPERIMENT LXIV.

On tearing asunder the jaw-bones of the salamander, we perceived at the bottom of the palate, the two eye-balls, of a sky blue, rendered paler by the whiteness of the membranes which enveloped them. Over these membranes were spread a great variety of vessels, whose capacity was only sufficient to contain a single globule; and the origin of which could not be traced without much difficulty: it was, however, easy to perceive them turn back towards the jaw-bone, where they formed a small vein, that took a direction towards the heart. The momentum of the blood appeared three times greater in this vein than in the ramifications from which it originated.

There is no organ which receives so many vessels as the lungs: every branch of the arterial trunk furnishes a number of globules which moisten the whole surface of the pulmonary membrane, excepting some small white portions into which the blood rarely penetrates. This fluid seemed, at first, not to be confined in any canal; and we only began to distinguish some traces of vessels in those points where the blood was accumulated in a very great quantity. The globules were of a very deep red colour, and moved singly in these vessels.

EXPERIMENT LXV.

I opened, in preparing the salamander, a middle-sized artery in the mesentery, from which issued a considerable number of globules, under the form of small oblong balls.

EXPERIMENT LXVI.

I examined a mesenteric vessel which received only a single series of globules at a time; they moved with languor, and at a sensible distance from each other: their form appeared the same as in the preceding experiment, excepting some, which were of a round figure, and of a much smaller size. Suspecting that these last were only the points of those which had appeared elongated, I followed their course through all the extent of the vessel, but their form and size never changed.

EXPERIMENT LXVII.

On a salamander and a green lizard.

Not satisfied with the two preceding experiments, I placed under the microscope a small drop

drop of blood drawn from a live salamander, and previously diluted with a little water, so that I could observe, individually, the globules of which it was composed. Some of them were of a round figure, a little pointed; others spherical, and about half the size of the former*. The venous and arterial blood presented the same phænomena; but in the green lizard the globules were of an oval form, and their size hardly equalled, by a fifth part, that of the round globules in the salamander.

EXPERIMENT LXVIII.

I examined, by refracted light, two small branches which anastomosed with a vein of a very

* The late celebrated anatomist, Mr. Hewson, in his Experimental Enquiry, &c. has informed us, that the globules of the human blood, or that of other animals, when diluted with fresh serum, or water impregnated with a given portion of any neutral salt, so as to imitate the natural serum, remained unaltered; and examined, in this way, the particles, improperly termed globules, appeared to be flat bodies, having a dark spot in the middle. This figure, he affirms, was observable, not only in extravasated blood, but also in that circulating in the vessels of living animals. These particles, however, when mixed with water, assumed a spherical figure, and afterwards dissolved, leaving the little sphere without any covering

very considerable capacity. The globules appeared, in the two first vessels, of a brilliant white; but hardly had they entered the opening into the second, until they were changed to a pale red. Upon the employment of reflected light, the shining white assumed a reddish shade, and the pale red was changed into a purple colour.

EXPERIMENT LXIX.

The internal teguments of the abdomen presented a net-work of vessels which I examined with refracted light. The blood, in the smallest branches, was of the colour of mother of pearl; but, upon accidentally tearing some of the ves-

covering whatever. Before the vesicle was entirely dissolved, upon inclining the stage of the microscope, the black spot was observed to turn and roll from one side to the other, like a pea in a bladder.

On the assumption that Mr. Hewson's experiments were accurate, we must conclude, that Spallanzani has been led into some fallacy by the employment of water alone, and hence, that his deductions, respecting the spherical and round figure of the globules, are by no means conclusive. In most of Mr. Hewson's experiments, the microscope, with a single lens, was employed.

R. H.

sels, the globules, when heaped together, assumed a reddish tint.

At the extremity of another small vessel, the blood had the appearance of lymph; but, in proportion as the vein augmented in diameter, this fluid became of a darker red.

EXPERIMENT LXX.

Having placed upon a plate of glass and stretched, with small hooks, a mesentery which I had raised up without detaching it from the intestines, I found the vessels full of blood. I made this experiment with reflected light, and used a large lens, which I could hold at a sufficient distance from the membrane to enable me to manage the vessels at pleasure, without discontinuing the examination. Upon handling different parts of the mesentery, the circulation was re-animated in all the vessels, and on making a large incision into a vein or an artery, a quantity of blood issued out, in proportion to the pressure employed on the sides of the vessel. The globules resembled small grains, or molecules, partly spherical and pointed, partly round, but of a smaller size. The purple colour of the vessels was changed into a yellowish red, a pure yellow, and even a transparent white, of which the globules participated in proportion to the abstraction of a smaller or greater quantity of blood. I repeated this experiment in a different manner, that is, by forcing the blood from the trunk of the vessel into its branches, until only a few globules remained, when it immediately became of a shining yellow, which was changed into red, in proportion as the globules found their way back into the trunk.

EXPERIMENT XXVII.

From the rupture of a small artery, a considerable number of globules were effused upon the mesentery, at some distance from one another, without, however, sustaining any diminution of motion. These were unquestionably subjected to the direction and impulse of some invisible fluid, which could only proceed from the injured vessel, since the mesentery had not previously afforded the least sign of humidity.

EXPERIMENT LXXII.

Two small mesenteric veins of a capacity sufficient to contain only one globule united into a trunk, in which a single series of red molecules circulated

circulated at a time. The trunk received alternately the blood which proceeded from these two vessels. When the globules of the one entered into the common canal, those of the other branch sometimes stagnated near the opening, and sometimes took a retrograde direction without having experienced the least collision; hardly however had the former entered the trunk, until the latter followed the same course. During half an hour I observed the progressive and retrograde motion of these globules, without ever perceiving them in contact with each other. This motion could only proceed from an intermediate fluid, agitated by the mobility of the globes re-acting upon those which were at rest, and impelling them to penetrate into the trunk.

EXPERIMENT LXXIII.

The young, as well as the full grown salamanders, are provided with gills, which like those in tadpoles, and small toads, consist of two appendices situated on each side of the head; and their edges are notched in such a manner as somewhat to resemble, when viewed through the microscrope, a stag's horn. These organs are usually six in number, three on each side of the head, and are commonly supposed to answer the purposes of respiration. The blood circulated

lated only in the vessels, on the exterior part of the gills, unless in some small branches which extended over their whole surface. At the beginning of each gill, went out an artery, which, after running along the half of their circumference, turned back and assumed the character of a vein, which stretched to the head of the animal, where it was concealed from the sight. The globules appeared to possess elasticity, from their susceptibility of elongation and change of figure; their size was equal to those in full grown salamanders, excepting only that they were all round and somewhat pointed. (Exp. LXVII.) The artery at first received several globules, but where it changed into a vein these corpuscules entered it only singly, the others by a shorter passage; that is, by the small transverse branches which formed towards the middle of the gills an inter-communication between the artery and vein. Such were the languid motion and reciprocal distance of the globules from each other in the small branches that any change which they experienced was easily distinguishable. Their size was inferior to the diameter of the vessels against whose sides they did not seem to experience the smallest friction. Upon reaching those portions of the branches which presented various curvatures, they were elongated

elongated so as to lose half their thickness; and even formed an angle more or less acute, corresponding to that of the vessel, but afterwards resumed their original form.

EXPERIMENT LXXIV.

On a green frog.

A prodigious number of small arterial and venous vessels, which formed frequent anastomoses and joinings with each other, were scattered on the web between the toes. After the animal became enfeebled, the heart seldom renewed its contractions; the effect of which, however, extended through all the ramifications of these vesels.

EXPERIMENT LXXV.

On several salamanders.

From the redness which the heart assumed in its diastole I could only expect to discover the coronary vessels during its contraction; it presented, however, nothing but imperfect traces of some reddish folds which sunk deep into its substance. I discovered at last in a very large salamander, that these folds were only so many vessels in which the rapidity of the circulation

in

in the systole was in proportion to its languor during the diastole. Their number were very considerable, and they appeared to receive at once several globules: but I was unable to determine whether they were arterial or venous vessels: it seemed, indeed, on the side of the aorta, that the blood took a direction from the apex to the base of the heart.

Convinced by experience that it was only in the very largest salamanders the coronary vessels could be discovered, I made, with this view, a great number of experiments upon these animals, the results of which were uniform. Lest any future observer should have recourse to too vivid a light, it ought, perhaps, to be mentioned, that I found it necessary to employ a beam of solar light refracted by means of a lens, in order to bring these deep seated vessels immediately into view.

EXPERIMENT LXXVI.

On three salamanders.

When the salamander had been prepared some time, the circulation was carried on with less rapidity in the small ramifications, than in the middle sized vessels, (Exp. LII.) but afterwards this inequality augmented in proportion as the strength

strength of the animal declined. Thus, the blood circulated with very different degrees of velocity in the middle-sized and small vessels of the mesentery, stomach, and intestines, for the space of twelve minutes, after which, however, although it maintained for a considerable time, the same momentum in the middle-sized vessels, in the small ones it abated by degrees, and in two hours entirely ceased.

The same inequality of circulation did not, however, prevail in all the vessels of the salamanders; as, for instance, in the numerous small arteries of the urinary bladder, the blood continued to circulate for more than thirteen hours, with the same quickness as in the middle-sized vessels.

EXPERIMENT LXXVII.

Having observed that the blood circulated some time with rapidity in the tissue of small vessels (Exp. LIII.) spread amongst the yellow streaks on the belly and breast of the salamander, I endeavoured to ascertain whether the motion of this fluid continued for a greater length of time in these than in several other small vessels situated on the stomach, intestines, ovaries, &c. the result of this examination was, that the circulation ceased in the latter after one hour and three quarters, but continued two hours longer in the former.

EXPERIMENT LXXVIII.

In order to discover whether the circulation ceased sooner in the vessels near to, than in those at a greater distance from the heart, I selected for this purpose the arteries and veins which were distributed among the yellow streaks upon the breast and tail of the salamander. In both for a considerable time, the velocity of the circulation was equal; it ceased, however, sooner in the latter than in the former.

EXPERIMENT LXXIX.

The results were the same as in the last experiment; the circulation having ceased sooner in the vessels at the extremity than in those at the origin of the tail.

EXPERIMENT LXXX.

Anxious to observe what effect the interrupted action of the heart would produce on the circulation, I compressed it with my finger so that it could neither contract nor dilate. The circulation, in one artery and one vein, at first languished, and in an instant afterwards wholly ceased;

ceased; but no sooner was the compression removed, than it recovered its former velocity.

The interruption of the heart'saction arrested arrested the circulation in several other vessels of a less diameter, not even excepting the smallest red capillaries. The circulation, however, ceased somewhat later in the veins than in the arteries, which in their turn first resumed the motion communicated to them by the action of the heart.

EXPERIMENT LXXXI.

After three seconds, the inertia of the heart was communicated to the vessels, which crept on the yellow streaks of the lower belly. Upon, however, removing the obstacle to the motion of the ventricle and auricle, the circulation immediately re-appeared. When the action of the heart was only partially suspended, the blood experienced a diminution of motion in proportion to the degree of compression.

EXPERIMENT LXXXII.

Hardly had the heart ceased to contract, until the circulation was arrested in the pulmonary artery, and became more languid in a small vein of the gall bladder, in which it continued to flow

only

only seven seconds. Upon the re-commencement of the heart's action the circulation in the artery immediately returned, and some seconds afterwards in the small vein.

EXPERIMENT LXXXIII.

The preceding experiment having been repeated upon the middle-sized veins of the lungs and mesentery, the blood ceased, and resumed at the same time in each its ordinary motion.

EXPERIMENT LXXXIV.

On two salamanders.

A ligature upon the trunk of the aorta suspended the course of the blood throughout the vascular system. After six minutes, having cut the ligature, the circulation became instantly evident in all the arterial and venous vessels.

EXPERIMENT LXXXV.

Upon a repetition of the preceding experiment, the blood after three quarters of an hour resumed a languid motion which, in the end, became very rapid.

EXPERIMENT LXXXVI.

On two salamanders.

The circulation suspended during fifteen hours by means of a ligature placed on the trunk of the aorta, was restored in the large vessels upon removing the tie; whilst it remained without any appearance of motion, in the greatest number of the small ramifications. After having been suspended during twenty hours the blood recovered its original motion.

SECTION III.

On the phænomena of the circulation in the large and middle-sized veins.

EXPERIMENT LXXXVII.

On several salamanders.

A vein appeared immediately under the peritoneum, remarkable not only for its size, but also for receiving no branches for about the space of an inch. In this vein, the circulation was so apparent, as to be easily distinguished without the assistance of a microscope: it was of a cylindrical figure, and visible from the base of the tail to the liver, where it was lost. If too much violence

lence had not been employed in preparing the animal, the blood flowed with uniform velocity throughout the extent of the vessel; but if, on the contrary, it had been much agitated, the circulation became unequal, and was carried on with greater rapidity at the origin than the termination of the vein.

EXPERIMENT LXXXVIII.

Another peculiarity of this vein was, that it contained a prodigious number of small gaseous bubbles, whose course was from the tail to the liver. Their size, for the most part, was so considerable as to fill the canal of the vein, from which resulted so much friction as to retard their velocity. The density of the bubbles appeared to augment upon the animal moving its tail. From an opening in a small branch some drops of blood escaped.

EXPERIMENT LXXXIX.

This vessel suggested the idea of repeating an experiment that I had made upon several arteries, to ascertain whether the globules had any intestine or rotatory motion. But although I examined them at different times, and in several vessels, they appeared to be only subject to the usual laws of the circulation.

EXPERIMENT

EXPERIMENT XC.

On several salamanders.

The circulation was less rapid in the peritoneal vein, than in those of the lungs: (Exp. LXXXVII.) the blood flowed in these with the same velocity as in the accompanying arteries. The pulmonary veins were universally of a conical figure, excepting those portions of them betwixt the ramifications, which were cylindrical: their size generally exceeded that of the correspondent arteries.

EXPERIMENT XCI.

On two salamanders.

The blood in the pulmonary veins was more red than that in the accompanying arteries; but this difference depended evidently on the larger capacity of the veins, which enabled them to contain a greater number of globules; for, upon examining these two species of vessels, in portions, where their diameters were equal, the blood appeared of the same colour. The circulation in the pulmonary veins upon the exposure of that viscus to the direct rays of the sun, can be readily observed without the help of a microscope.

The blood in the pulmonary veins augmented in velocity, in proportion as it approached the trunk: it, however, in passing from the ramifications into the trunk, with which they anastomosed at right or acute angles, preserved its usual momentum.

The lungs having considerably collapsed, in consequence of a slight puncture, the blood stopped in several ramifications, and even in the trunk it lost the greatest part of its motion.

EXPERIMENT XCII.

I received, in two watch-glasses, some drops of blood from the aorta and vena cava of a living salamander. The redness and density of the arterial and venous fluid appeared the same. Upon being equally dried, and subjected to trituration, they were found to be composed of the same elements.

EXPERIMENT XCIII.

The diameter of the axillary vein was much larger than that of the corresponding artery: the blood flowed with the same rapidity, where the one emerged from, and the other entered the body of the animal. This velocity was

equal,

equal, or little inferior to that of the pulmonary fluid.

EXPERIMENT XCIV.

The surface of the palate presented a little below the globe of the eye two parallel veins, in which the blood circulated with the same velocity as in the pulmonary vessels.

EXPERIMENT XCV.

The teguments of the breast and belly covered on each side a longitudinal vein, which anastomosed with several lateral vessels. Its diameter, which was at first very narrow, augmented as it received a greater number of branches. The circulation increased in proportion to the size of the vessel, and almost equalled in the widest portion of its diameter, the quickness of the arterial and venous blood of the lungs.

EXPERIMENT XCVI.

The trunk of the mesenteric veins, as well as those portions comprised between the branches to which they gave rise, were of a cylindrical figure. These veins were much more numerous and larger than the attendant arteries, and the blood circulated with greater velocity in the trunk than the branches. In the arterial and venous vessels of a given diameter, the blood had the same momentum, and the same colour.

EXPERIMENT XCVII.

On several salamanders and frogs.

The blood flowed with more velocity in the pulmonary, than in the mesenteric veins of the salamander: these last presented a variety of different ramifications upon the intestines, without appearing, in the least, to impede the circulation.

I employed the apparatus of hooks in examining the mesenteric vessels of five frogs. In two of the mesenteries, the blood circulated more rapidly in the arteries than the veins; in two others, the velocity was diametrically opposite, and in the fifth, its motion was the same in some arterial and venous vessels.

Such different results made me anxious to examine the mesentery in an equal number of frogs, allowed to remain in its natural position; all the five presented an equality of motion between the venous and arterial blood.

EXPERIMENT XCVIII.

To the natural curvatures I added several artificial ones, yet the blood flowed with facility from the one to the other. Such was their disposition, that they sometimes formed a simple contour, sometimes an angle more or less acute or obtuse. I had it in my power to give a direction to the venous fluid, conformable or contrary to its usual motion; yet, amidst the diversity of so great a number of windings and convolutions, the circulation preserved an equal velocity.

EXPERIMENT XCIX.

The red globules in the mesenteric veins appeared to possess neither intestine nor rotatory motion, and flowed, especially when the circulation was languid, much more rapidly in the center, than towards the sides of the vessels.

Although these vessels had a considerable diameter, the blood scarcely exhibited any signs of motion, and even that was only sensible in the series of globules corresponding to the middle of the canal; while those, in contact with the sides, remained perfectly at rest. This experiment was found to succeed better when the mesentery was kept stretched with hooks, and the examination made with refracted light. The blood oscillated in several mesenteric veins, and the circulation languished in some others. These irregularities, when the mesentery was displaced and stretched with pins, have been already noticed: the globules, which moved along the sides of the vessels, hardly changed their situation; while, on the contrary, those in the middle circulated with some rapidity: the first, besides, lost their motion before the second.

EXPERIMENT C.

In consequence of having been accidentally opened, there remained so little blood in the trunk of the mesenteric vein, that I could readily distinguish the globules at the sides from those in the middle, which had a much more rapid motion than the former.

EXPERIMENT CI.

Anxious to observe if the arteries were subject to the same law, I selected two of the largest in the mesentery; but the rapidity of the circulation was so great, that I found it necessary to wait until it diminished. In about three hours the blood stopped during the diastole, and advanced

vanced during the systole of the heart. I seized the last moment of the progression of the blood to examine the motion of the globules; it ceased sooner in the circumference than in the axis of the vessel. Three quarters of an hour later the blood assumed a retrograde motion in the diastole, and the globules in the middle became first subjected to this direction.

EXPERIMENT CII.

On several salamanders.

I repeated the experiment relative to the velocity of the blood, in the trunk and veins of the mesentery (Exp. XCVI.). The salamander was left upon the gibbet until the circulation was on the point of ceasing, when the blood scarcely moved in three or four veins; whilst, in their trunks, it was much more rapid as it approached the heart.

EXPERIMENT CIII.

The capacity of the venous mesenteric trunk equalled only by one half the sum of the capacities of its branches, and it was equally so in all the other mesenteric veins, compared with their branches.

EXPERIMENT CIV.

A mesenteric vein was accidentally straitened so as scarcely to admit any red globules. In passing this narrow place, the blood augmented in velocity, but hardly emerged before resuming its original motion.

In the straitened portion of the vessel were occasionally formed several air bubbles, which followed the course of the circulation.

EXPERIMENT CV.

On several salamanders.

I conceived, from former experiments, that the blood rarely contained any air bubbles ; future researches have, however, convinced me that we can readily produce and increase their number. When I stretched the mesentery in such a manner that the eye could take in at once, through a microscope, all the veins distributed to this membrane and the intestines, I never failed, upon slightly handling these vessels with forceps, to be agreeably surprised by the appearance of a prodigious number of gaseous bubbles, somewhat resembling oblong spheroids, which, almost completely filling the cavity of the vessels, pursued a languid course towards the mesentery ;

mesentery ; but the velocity of these molecules increased in proportion to the size of the vessel ; their figure became rounder ; they even acquired a form entirely spherical, and flowed with the greatest rapidity one after another into the mesenteric trunk, in which they circulated with the same celerity as the fluid which served them for a vehicle. Although these bubbles, in consequence of lateral pressure, were, for the most part, of the same size, yet some of them were smaller than others, they were all, however, much larger than the red globules of the blood. Upon ceasing to irritate the intestines and mesentery, the number of air bubbles diminished by degrees, and often altogether disappeared ; on the application of a fresh stimulus, however, they re-appeared, but only in those parts to which the effects of the irritation extended.

EXPERIMENT CVI.

Three branches proceeded from the spleen, whose union formed the splenic vein. After having received another branch, which came from the stomach, it anastomosed with the venous mesenteric trunk. This vessel appeared at first to be an artery ; for the blood, instead

of

of flowing from the branches into the trunk, passed from the trunk to the branches, and emptied itself entirely into the interior of the spleen. But I soon perceived that my error proceeded from having reversed that viscus, so that the blood was stopped in this vessel whilst it circulated in the venous trunk with a rapidity, which, being communicated to the fluid contained in the splenic vein, forced it to take a retrograde direction into the branches, and from the branches to the spleen; upon, however, replacing it in its natural situation, the blood recovered its usual course, that is, from the spleen to the branches, from the branches to the vein, and from the vein to the mesenteric trunk. In the splenic vein the motion of the blood was more rapid than in its ramifications.

EXPERIMENT CVII.

On two salamanders.

As it appeared to me that the languid motion of the blood might have arisen from the displacement of the spleen, I repeated the foregoing experiment upon two other salamanders, without altering the natural position of this viscus; but it produced no effect whatever upon the

rapidity

rapidity of the circulation. I have not been able to discover any vein in which the blood flowed with greater languor.

EXPERIMENT CVIII.

On five salamanders.

The course of the blood was very languid in the middle sized veins of the liver. Several small branches proceeded from the extremity of its lobes, which, after having crept openly upon the surface of this viscus, formed by the union of several other branches a middle-sized vein, which was hardly observable, except with a strong light, from the deep colour of the liver. The velocity of the circulation in this vessel, was three times less than in the mesenteric veins.

This experiment having been repeated upon four other salamanders, the results were somewhat different. The motion of the blood, however, in the mesenteric, was uniformly more rapid than in the hepatic veins.

EXPERIMENT CIX.

On three salamanders.

The blood is brought back to the heart by the superior and inferior vena cava; the first is composed of two trunks, each of which anastomosed with two branches, which chiefly arose from the axillary veins. The heart was situated between these two trunks; the left had a diameter more extensive than the right.

The inferior vena cava, which received the greatest portion of the blood, was much larger than the united trunks of the superior. It derived its origin from the extremity of the tail; and, having reached the abdomen, where its capacity became very considerable from the numerous ramifications received in its passage, it penetrated into the liver, whence it went out divided into a double branch, which, after uniting into a single trunk, and receiving the blood of the pulmonary veins, entered into the auricle of the heart.

Many minute vessels crept upon the sides of this large vein, of which I could neither distinguish the order nor the species.

The two *venæ cavæ*, having more transparent coats than the descending aorta, rendered the course of the blood very perceptible.

EXPERIMENT CX.

On four salamanders.

Although a great number of branches anastomosed with the inferior vena cava, the circulation was not carried on with greater rapidity than in the middle-sized veins of the mesentery : this held equally true in the superior cava. The blood contained in the trunk of these two vessels circulated and penetrated, by alternate jets, into the auricle of the heart : they had each a pulsatory motion, corresponding to their size. Upon contraction, their diameter diminished, and the blood flowed with rapidity into the auricle ; but this, during the systole, counteracting the influx of a part of the blood, it was forced to regurgitate in the cavas, where it stagnated, or took a retrograde direction, in proportion to the strength of the animal.

EXPERIMENT CXI.

The greatest part of the veins, which anastomosed with the inferior vena cava, were very small in relation to the trunk ; in like manner the four branches which went out from the left ovary were of a very small diameter. The inferior vena cava was sixteen times greater than two of these branches; the capacity of the others was still less considerable, and appeared even one hundred and twenty times smaller in the fourth branch than in the vena cava.

The male salamander possessed similar vessels, which derived their origin from the testicles; one of which was of an equal size with that of the fourth branch in the female salamander. The blood circulated in these veins with the same velocity as in the vena cava; and even lost nothing of its velocity in flowing into this vessel, although it made, with several branches, an angle of more than eighty degrees. Upon augmenting or diminishing the number of angles, by changing the relative situation of the parts to which the branches were attached, some irregularities in the circulation immediately ensued; but these very soon ceased, and the blood resumed its original velocity, without afterwards experiencing, from the various flexures, the least change in its motion.

EXPERIMENT CXII.

Several small veins crept on the sides of the aortal trunk, and by their union formed a single canal

canal in which the blood moved, *per saltum*, and in a direction contrary to the arterial fluid. During the dilatation of the aorta, the circulation was arrested in the vein and its branches; during the systole, however, it recovered its momentum, and flowed with rapidity from the ramifications into the small trunk.

EXPERIMENT CXIII.

On two salamanders.

This small vein having reached the beginning of the aorta, anastomosed near the heart, with one of the trunks of the superior cava; the blood contained in this vein, propelled by the contraction of the aorta, forced a passage across that which filled the trunk of the cava; whence resulted a kind of jet, which lengthened and enlarged during the contraction of the aorta, but shortened and diminished during the dilatation of that vessel. We may not unaptly compare this phænomenon to certain springs, which have their origin in places covered with water, and which, by forcing a passage to its surface, produce in the midst of the water itself an impetuous bubbling motion. The trunk of the cava exceeded in diameter, that of the small vein in the proportion of 235 to 1.

EXPERIMENT CXIV.

Of two middle-sized veins, one received near the heart a branch twenty-five times smaller, the other three branches which had each a diameter forty times less. Although these veins formed between themselves very acute angles, the blood preserved its original motion in passing from the one to the other.

Although this examination regarded the middle-sized veins, the relation of it here appeared to me proper, because it tended to confirm the result of experiments CXI. and CXIII.

SECTION IV.

Upon the phænomena of the circulation in the vascular system of the chick, during the process of incubation.

EXPERIMENT CXV.

On five eggs, after forty hours incubation.

The umbilical vessels were already visible upon the membrane which surrounded the white of the egg. Two arteries and two veins were likewise observable: the first traversed the whole surface

surface of the body, and the last corresponded to the extremities of the chick, which resembled a small worm. The blood which verged towards a yellowish red, circulated somewhat slowly, and the red colour predominated in proportion as the vessels augmented in diameter, that is, as they approached the heart. During the systole this viscus became so pale as not to be perceivable; but, during the diastole it recovered a reddish tint, which rendered it very visible. Its contractions were frequent, and the blood moved by jets, advancing, during the systole, and stopping during the diastole.

It had flowed scarcely fifteen minutes, before the heart ceased to beat, and the blood at the same time discontinued its motion. All the vessels remained full of this fluid; and the molecules of which it was composed, were already of a globular form, and of the same magnitude as after having acquired a vivid and purple red. Upon the rupture of any vessel, the blood immediately escaped, and assumed a reddish colour, from the accumulation of the globules round the opening.

The circulation was not observable until after forty hours incubation.

EXPERIMENT CXVI.

On five eggs, after two days and four hours incubation.

The pulsations of the heart were very frequent. This organ was situated as in the centre of a circle, at the circumference of which terminated the ramifications of two arteries in several small continuous veins. The union of these formed two principal trunks, in which the circulation was carried on with greater rapidity than in their branches.

All the arterial ramifications, however, did not extend to the circumference; some of them, before reaching it, took a retrograde direction, and passed into veins, which, in like manner as the former, returned towards the heart. The blood moving by jets in the two arteries, circulated during the systole, through a less space than in the preceding experiment; stagnating on every diastole, and resuming its course in the following systole; during which, it preserved in the branches and ramifications proceeding from the circumference, the impulse communicated to the trunk; but its velocity was abated at the beginning of those ramifications which did not extend

extend to this point. It lost even that increased momentum, in proportion as the distance from the circumference increased; having then an uniform but very slow course. The regularity of the circulation did not appear to be in the least disturbed by the blood flowing from the ultimate arteries into the incipient veins. This fluid appeared of a yellowish colour in the extremities of the vessels, somewhat red towards the middle, and of a deep red near the heart; the globules exhibited neither intestine nor rotatory motion.

EXPERIMENT CXVII.

On three eggs, after three days incubation.

The four umbilical vessels were augmented in all their dimensions; as well as the heart, which communicated a more rapid motion to the arterial blood; in consequence of which, this fluid circulated during every systole through a much greater space than on the second day: it besides preserved a small degree of motion, during the diastole.

The blood was, throughout, of a red colour, a little paler, however, in the small vessels. At the time of its dilatation, the heart became very red; and unless when the blood stagnated in the capillary vessels, it was not altogether without colour even during its systole.

The two arteries were partly covered by two veins, in the same manner as the trunk and branches of a tree are entwined by a parasitical plant. The ultimate ramifications of one of these veins derived their origin from the circumference, those of the other from the arterial terminations, without our being able, however, to ascertain the precise point of their junction.

Several other small veins were easily distinguishable, which, after uniting with the arterial ramifications, proceeded singly to the inferior part of the chick, and disappeared. The capacity of the arteries, at their junction with the veins, was such as only to admit four or five globules at once, and the venous and arterial blood were of the same colour.

EXPERIMENT CXVIII.

On five eggs, after three days and four hours incubation.

The veins were so situated above the arteries, as to conceal the trunks, and the greatest part of

 their

their branches; the circulation could therefore only be observed in the smallest arterial ramifications. The blood flowed in the branches more rapidly during the systole than the diastole, but its course was uniform in the small ramifications. The two veins which proceeded from the extremities of the chick (Experiment CXV), were cylindrical; and in them the blood moved with uniform velocity; but, in those which crept upon the arteries, the circulation was more rapid in proportion as it approached the heart, and they had only a cylindrical figure in those portions situated between the ramifications.

The arterial and venous vessels had little colour; but the heart was very red, especially during the time of its dilatation. In the space of an hour, the heart remained altogether inactive; a moment later the arterial blood, and afterwards the venous fluid ceased to circulate.

Upon the recovery of the heart's action, (which was sometimes spontaneous, sometimes occasioned by touching this organ, or even moving the microscope), the circulation was instantly reestablished. The vessels remained full of blood when the motion of the heart had entirely ceased, but the smallest ramifications were frequently not discernible.

EXPERIMENT CXIX.

On two eggs, at the same period of incubation.

The phænomena were the same as in the preceding experiment, but the incubation appeared somewhat farther advanced: the blood was of a brighter colour, the motion more rapid, and the vessels of a larger size. The allantois was now perceivable, overspread with small veins, in which the blood circulated with rapidity.

EXPERIMENT CXX.

On one egg, at the same period of incubation.

I again observed the appearances of the circulation, when the action of the heart had considerably diminished, and which had only contracted for an hour and a half, upon the application of a stimulus. After allowing it to remain at rest for six, nine, and even twelve minutes, I revived its excitability; the blood which had stagnated during all that time, immediately resumed its course, which continued until the heart had entirely ceased to beat. After nineteen minutes inaction, I had again recourse to the most powerful means of excitement; it only, however, dilated three or four times, and the circulation was extremely feeble.

EXPERIMENT

EXPERIMENT CXXI.

On five eggs, after three days and twelve hours incubation.

The heart became very red during the diastole, and the blood moved by jets throughout the extent of the arteries, and in the origin of some veins. The union of these vessels with each other was accomplished in the following manner; two or three arterial branches having reached a greater or less distance from the heart, took a retrograde direction towards this viscus, and from the reflection of their re-curved branches, gave rise to a vein which after forming several ramifications, united into a single trunk. Other two arteries passed into a continuous vein of a considerable size, which directed its course towards the heart.

In this junction, however, between the arteries and veins, whatever might be the diversity of windings, and convolutions, of angles, and sinuosities, the blood experienced not the smallest retardation.

It was impossible to establish a comparative estimate between the velocity of the arterial and venous blood; the first circulated during every systole, with greater rapidity than the second, and inversely during the diastole of the heart. The heart ceased to pulsate for an hour and a half, and the circumference in which the vessels terminated was almost invisible; the blood stagnated, or flowed very slowly when these vessels could be again observed; but had on the contrary a very rapid motion in those nearer the heart.

The heart moved irregularly during other two hours, and the blood circulated and stagnated alternately, whilst the arterial fluid was arrested, the venous only experienced a retardation; occasioned, no doubt, by the interval between the contractions being so protracted, that the momentum could only abate in the venous system.

EXPERIMENT CXXII.

On two eggs, at the same period of incubation.

Having conjectured that the jets of the arterial fluid might depend upon the immediate impression of the atmosphere, I repeated the foregoing experiment, without tearing the membrane between the yolk and white of the egg, the coats of which were not so thick as wholly

to

to preclude a view of the circulation; the result however was not different.

EXPERIMENT CXXIII.

On one egg, after four days incubation.

The blood in the chick had not hitherto appeared equally red, or displayed such rapidity of motion, as in the present experiment, yet, the circulation was still very far from being carried on with the same velocity as in salamanders, frogs, &c. &c. The umbilical vessels which were only distributed to the base of the egg, had been so much displaced, that they could only be examined separately. At whatever angle a branch went off from any of the two veins situated above the arteries, the blood flowed from the one to the other with an uniform motion: in another vein it assumed an oscillatory movement, took a retrograde direction in some of its branches, and stagnated in the extreme ramifications.

These irregularities appeared, however, to proceed from some injury sustained during the preparation.

EXPERIMENT

EXPERIMENT CXXIV.

On two eggs, at the same period of incubation.

None of those irregularities occurred which were remarked in the last experiment: in every other respect the results were the same. Till now, no trace of lymph had been discovered in the blood of the chick. The globules moved almost in contact with each other, and were of a pale red colour.

EXPERIMENT CXXV.

On two eggs, after four days and six hours incubation.

The external globe of the eye was already become very visible, and had several small vessels scattered over its surface; their coats, however, were so thick, that it was impossible to observe the circulation, or to determine whether they were arteries or veins.

The circulation was carried on at the circumference in the following manner: The blood brought to it by a great number of arteries, was carried back to the heart with equal velocity by a prodigious number of veins. Their diameter was three or four times less than at the circumference, where the blood displayed an uniform course, but in opposite directions, according as it flowed in the arteries or the veins.

EXPERIMENT CXXVI.

On one egg, after five days incubation.

This was the first time that the chick moved its membranes, upon being exposed to the influence of solar light. The circulation was from this time carried on with the same rapidity in the four umbilical veins, as in the vascular system of cold-blooded animals.

The allantois had become much larger, and was entirely vascular; the circulation enabled us to distinguish the veins from the arteries, which were prolonged even beyond the allantois, where they changed into so many veins, which terminated at the point where this receptacle communicated with the chick. The blood flowed with uniform velocity in these veins, but circulated by jets in the arteries from which they originated.

The circulation was maintained in this egg during two hours and a quarter; it ceased in the vessels

vessels at the circumference sooner than in those at the centre, and, excepting the most extreme ramifications, they all remained full of blood.

EXPERIMENT CXXVII.

On one egg, at the same period of incubation.

Besides the appearances already mentioned, this egg exhibited, 1, A very great variety of small vessels which interlaced the whole body of the chick: 2, An augmentation of flexures and convolutions, which neither accelerated nor diminished the momentum of the blood: 3, Such a thickness in the coats of the four veins, that the circulation in them was scarcely observable: 4, A deeper colour of the blood, and a velocity in the circulation, perhaps, even greater than in frogs and salamanders: lastly, A very remarkable velocity in the extreme ramifications, and an uniform motion in the greatest number of the arteries.

EXPERIMENT CXXVIII.

On four eggs, at the same period of incubation.

The results of this were conformable to those of the former experiment.

EXPERIMENT

EXPERIMENT CXXIX.

On one egg, after six days incubation.

The superior part of the head was somewhat transparent, and resembled an air bubble ; its vessels were very numerous, and the motion of the blood was perceived through the amnion. One of the arteries gave origin to several branches, in which the circulation was carried on by small jets, less sensible, however, as these diminished in capacity. I was not able to discover the precise point at which the union took place between the arteries and veins.

I rent the amnion, in order to obtain a more accurate view of the vessels, but they were mostly all ruptured, excepting twenty small veins, the union of which formed a common trunk, terminating in the contexture of the skin, and the blood had a more rapid motion in the trunk than in the ramifications. It was impossible to characterize a small vessel which extended from the posterior part of the eye to the pupil.

EXPERIMENT CXXX.

On one egg, at the same period of incubation.

Most of the venous trunks were so opaque, that the circulation was only observable in the branches

branches and their subdivisions, in which the blood had a very red colour, and circulated with the greatest rapidity. The chick had dug in the yolk of the egg a small cavity, into which it had sunk: and wherein inter-communicated several venous and arterial vessels. The greatest number of these had a capacity only sufficient to receive, at a time, a single series of globules that moved with considerable celerity, although at a given distance from each other. The small ramifications were of a cylindrical figure; and the globules almost came in contact with their sides. The impulse of the heart extended to the arterial and venous vessels.

I rent the amnion so as to uncover the chick without injuring any of its parts; the extremities already evolved were strewed over with a great number of small vessels, from each of which originated a vein that terminated in the body of the animal. To the head, the neck, the back, and the tail, were distributed an infinite number of arteries and veins, which presented the same appearances as the umbilical vessels.

EXPERIMENT

EXPERIMENT CXXXI.

On three eggs, after seven days incubation.

The wings, thighs, and legs of the chick, were now evolved; the diameter of the vessels had much increased, and several others became visible.

EXPERIMENT CXXXII.

On one egg, after eight days incubation.

The membrane of the yolk had its appropriate vessels, situated underneath the umbilical arteries and veins in the white of the egg; and in which the circulation was very apparent.

After an attentive examination for one hour and a half, these vessels presented the same appearances as in the foregoing experiments. The beak and inferior part of the orbit of the eye were separated by two vesicles, partly covered by some arterial ramifications, in which the blood circulated by jets, equally rapid as frequent.

EXPERIMENT CXXXII.

On one egg, after nine days incubation.

The membrane of the yolk was furnished with a large artery that had some resemblance to a

worm

worm twisting and unfolding itself. A pulsatory motion was evident throughout the extent of this vessel; the circulation was carried on by jets; and during the diastole and systole it remained full of blood. To its sides adhered a small vein, in which the motion of the blood was sensibly affected by the continual pulsation of the artery. This vein furnished a branch of a diameter three times smaller, wherein the blood moved with the same velocity as in the trunk, although they formed with each other almost a right angle.

EXPERIMENT CXXXIV.

On two eggs, at the same period of incubation.

I endeavoured to ascertain whether the arterial stopped before the venous fluid. The circulation abated and ceased equally throughout the arteries and veins in the membranes of both the white and yolk of the egg. The languor of the circulation enabled me to observe if the blood flowed more rapidly in the middle than round the sides of the vessels, and I found that its momentum was greatest in the axis.

EXPERIMENT

EXPERIMENT CXXXV.

On three eggs, after six days incubation.

Upon the toes of the chick crept a small artery; this vessel, after having reached their extremities, changed into a vein, the trunk of which ascended towards the opposite side. The union of four of these veins formed upon the inner part of the foot, a much larger canal, wherein the blood circulated with twice the velocity it had in the small ramifications. The acceleration of the arterial fluid extended even to the veins.

EXPERIMENT CXXXVI.

On one egg, after eleven days incubation.

Besides the appearances in the foregoing experiment, a net-work of arteries and veins had become evident upon every toe.

EXPERIMENT CXXXVII.

On one egg, after twelve days incubation.

Near the pupil of the eye appeared several venous ramifications, whence went out a vein, which was distributed to the iris. The blood stagnated in some branches, but circulated quicker in the vein than in those branches which possessed motion.

The space which separated the eyes was occupied by a net-work of cutaneous vessels. In one series of these vessels the blood was motionless, and in the other had only a very languid circulation. Upon the *meatus auditorius externus* were spread many small vessels, whence issued an artery, which diverged into several ramifications upon the head of the chick. A venous plexus formed under the ear a trunk, which disappeared in the neck. Although the egg had been opened an hour and three quarters, the blood moved in this trunk with the greatest rapidity.

EXPERIMENT CXXXVIII.

On one egg, after thirteen days incubation.

The diameter of the umbilical vessels had so much augmented, as to fill the whole space between the base and the apex of the egg. Having opened the intermediate portion, I observed three veins, which brought back the blood at an obtuse angle; they did not anastomose, for a certain extent, with any vessel; but, upon receiving new branches, the motion of the blood became

became immediately accelerated. Having broken a greater portion of the shell, I perceived a small artery, which changed into a vein, the trunk of which pursued a direction towards the heart parallel with the vessel whence it originated, without receiving any other branch. The motion in these two vessels were equal during three quarters of an hour, after which the arterial fluid was evidently actuated by the impulsion of the heart. I had not, until now, observed any gaseous bubbles in the vessels of the chick: they were produced at intervals, and passed rapidly from the branches into the venous trunks, where they were still apparent, although the thickness of the membranes did not permit us any longer to observe the circulation of the blood.

EXPERIMENT CXXXIX.

On one egg, after fourteen days incubation.

The body of the chick being now covered with feathers, the circulation could only be observed in the neck, which was yet bare, and in which a large vein was apparent, wherein the blood flowed with great rapidity, although the chick exhibited no external signs of life. This vessel anastomosed with a great number of ramifications; and the blood entered the trunk with its usual quickness, although the ramifications had a diameter fifty times smaller.

From every side of the beak went out two small veins, which poured, by degrees, the blood into the interior parts of the head. The tongue, and inner sides of the mouth, were supplied with a prodigious number of small vessels, in which the circulation was so languid, that we could scarcely distinguish whether they were arteries or veins.

EXPERIMENT CXL.

On one egg, at the same period of incubation.

The membrane investing the yolk at the apex of the egg, received a large artery, in which the pulsations corresponded to those in a double branch proceeding from it. But the thickness of its coats permitted us only to observe the circulation in the smallest branches. The acceleration experienced from the impulsion of the heart, succeeded with so much frequency that the eye could scarcely distinguish it.

EXPERIMENT CXLI.

On one egg, after fifteen days incubation.

The preparation of the egg had so much disordered the vascular system, as to give to the blood

blood a languid, rapid, oscillatory, or retrograde motion, according to the distribution of the vessels. The feathers, which covered the body, prevented us from observing the circulation which was not now even apparent in the extremities where the vessels had penetrated, and were almost concealed in the contexture of the skin.

EXPERIMENT CXLII.

On one egg, after sixteen days incubation.

Two large veins in the membrane, which covered the apex of the yolk, conducted rapidly towards the heart several air bubbles: their motion was perfectly evident, although we could not distinguish the course of the blood, from the increased thickness of the tunics.

The rupture of any vessel produced an immediate effusion of blood.

EXPERIMENT CXLIII.

On four eggs, after nineteen days and twelve hours incubation.

Towards the end of the incubation, the umbilical vessels adhered so closely to the pellicle lining the interior parts of the shell, that it was impossible not to rupture them in raising up this membrane: by moistening it, however, with a little tepid water, it was easily detached without tearing any of the vessels. In the trunk and the principal branches, the circulation could not be observed, and scarcely even in the capillary ramifications; in which, however, it had not before appeared equally rapid. The globules possessed only a progressive motion.

EXPERIMENT CXLIV.

On five Turkey eggs, after four days incubation.

These eggs presented two appearances different from those of the domestic fowl. 1. The umbilical veins were not incumbent upon the two arteries (Exp. CXVII, CXVIII); they were, on the contrary, separated, so that the blood formed four currents, two proceeding from, and two which returned to the heart. These four vessels possessed an equal diameter; and in proportion as the blood reached nearer to the heart, its circulation became more rapid in the veins, and was carried on by jets in the arteries. 2. The momentum produced by the action of the heart, was communicated to all the veins which arose from the flexures of the arterial vessels; with this difference, however, that it diminished as it approached the heart.

SECTION

SECTION V.

On the phænomena of the circulation in the vascular system of tadpoles, from the period of exclusion to their transformation into frogs.

EXPERIMENT CXLV.

Second day after exclusion.*

These animals are formed of a flat and elongated tail, and a small globe, which, in conformity to the common mode of expression, we continue to denominate the head, although it includes the greatest part of the body. The circulation was not yet visible: but we began to distinguish the pulsations of the heart, like a point continually in motion, without, however, being able to ascertain whether it contracted or dilated; the transparency of its sides permitting us only to observe the motion with which it was agitated.

During the first day, the *punctum saliens* was not discernible.

* In order to provide myself with a sufficient number of tadpoles, I hatched the eggs in a vase half filled with fountain water. I supported the young with the water lentil, and they were evolved and encreased in this manner, without any other attention than renewing the water and food.

As the tadpoles perished when out of water, I therefore examined them in a watch-glass filled with this fluid.

EXPERIMENT CXLVI.

Third day.

The *punctum saliens* had now become more evident, but preserved, however, its transparency.

EXPERIMENT CXLVII.

Fourth day.

The transparency was not uniform; that is, if, during the moment A, the *punctum saliens* was transparent, it assumed, in the moment B, a tint somewhat red.

EXPERIMENT CXLVIII.

Fifth day.

This reddish tint arose from a few sanguineous globules contained in the cavity of the *punctum saliens*, which had now become much more considerable; and its transparency was occasioned by the expulsion of these globules.

EXPERIMENT CXLIX.

Sixth day.

The gills presented the first appearance of the circulation: in the circumference of each, inter-

communicated

communicated an artery and vein. The first was extended from the base to the apex, and the other returned from the apex to the base; the blood stagnated in this artery and vein, and, a moment afterwards, recovered its former course. These alternations were periodical, and resembled a wheel, stopping after every three or four revolutions. This phænomenon proceeded from the action of the heart; for on fixing at once, both this viscus, and one of the gills, I beheld the circulation restored at every systole, and ceasing entirely when the heart dilated and became filled with blood. This fluid was white, or rather of no determinate colour.

The globules were of the same size and figure as in full grown frogs; and usually circulated at a small distance from each other.

EXPERIMENT CL.

*Eighth day**.

The results were the same as in the foregoing experiment; excepting only that the gills were

* Although I observed the circulation of the blood at different periods from the exclusion of the tadpole to its transformation into a frog, I shall only here point out the phænomena which have an immediate relation with the subject I had proposed to investigate.

more completely evolved, and that the circulation had begun in the tail.

EXPERIMENT CLI.

Tenth day.

The whirling course of the blood (Exp. CXLIX.) was more rapid, and the sides of the tail had become strewed over with blood vessels.

EXPERIMENT CLII.

Twelfth day.

The gills disappeared by degrees one after another. The whirling motion had not ceased, but the revolutions were less rapid. The vessels of the tail had augmented, and we could now discern an artery and vein extending in a direction almost parallel from the apex to the base of the tail; and to which we have given the appellation of *large vessels*, either because they very considerably exceeded in size the small branches already mentioned, and to which they gave rise; or because they furnished and received all the blood which was distributed to the different parts of the tail. The greatest number of these ramifications admitted only a single series of globules at a time, and which moved at a considerable distance from each other, and with more rapidity during the systole, than the diastole of the heart. The globules circulated, in like manner, through the artery, and in the beginning of the large vein; but in proportion as this vein ascended along the tail, the blood lost its inequality of motion. Some vessels besides, were perceived at the circumference of the head, wherein the blood abated in its course during each dilatation, and augmented in quickness upon every contraction of the heart.

The pulsations of the heart were very frequent, and the blood contained within its cavities was more evident. It retained upon every systole a small quantity of this fluid, so that a reddish tint predominated, the brilliancy of which became considerably more vivid during the diastole.

EXPERIMENT CLIII.

Fourteenth day.

The capacity of the two great trunks in the tail had augmented as well as the number of vessels, and the quantity of blood. In those branches which formerly transmitted but a single series of globules at a time, several now circulated together, and the blood in the great artery flowed

flowed almost uniformly, but with more than double its former rapidity.

EXPERIMENT CLIV.

Sixteenth day.

The blood, which was uniformly transparent in the subordinate branches, showed in the two great trunks a reddish tint. That which escaped through an opening made in the vessels of the tail or head, was tinged with the same colour; but, when viewed by refracted light, assumed a yellow hue.

EXPERIMENT CLV.

Eighteenth day.

The two large vessels, from this time, discernible through the whole length of the tail, anastomosed at a very acute angle near its apex, in such a manner, that they continued to diverge in proportion as they receded from the heart. The circulation, which had augmented in velocity, was not now disordered by the accelerated motion of the ventricle; excepting only, that in proportion as the artery approached the extremity of the tail, and subdivided upon its sides, the momentum of the blood abated and increased in the vein, as it received a greater number of branches and approached the base of the tail. At a given distance, the capacities of these vessels, as well as the momentum of their fluids, were equal; and that contained in the two large trunks had some resemblance to blood diluted with water.

EXPERIMENT CLVI.

Twenty-second day.

The middle-sized and small partook of the reddish colour of the large vessels; and the globules, which had at first (Exp. CLII.) circulated at a considerable distance from each other, were now so augmented as to come into contact. The other results were conformable to the preceding experiment.

EXPERIMENT CLVII.

Twenty-sixth day.

The tadpoles were now about a quarter of an inch in length. Their motions when in water were performed in every direction and with the greatest rapidity. The pulsations of the heart were very frequent, and when examined by an ordinary microscope, it resembled a small red body, the brilliancy of which augmented during

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the diastole; viewed afterwards through a more perfect lens, it appeared almost full of blood, much more so, however, when dilated than during its contraction. Notwithstanding the frequency of its pulsations, the circulation stopped in the aorta, which was now visible at every diastole of the heart. In all the other arteries the blood had an uniform motion; in a few, however, it flowed more rapidly, particularly in those of the tail.

In order to observe with accuracy the blood contained in the heart and the aorta, it was necessary that the tadpole should be placed on its back, and these organs illuminated by the direct light of the sun; the teguments of the belly being sufficiently transparent to transmit its rays.

EXPERIMENT CLVIII.

Thirtieth day.

The velocity of the circulation had encreased throughout the vascular system; and the redness of the blood was in proportion to the capacity of the vessels; but this fluid was yet far from having acquired that florid purple which characterizes the arterial and venous blood in frogs.

EXPERIMENT

EXPERIMENT CLIX.

The same day.

Although the blood had an uniform motion in all the vessels, except the aorta, it was, however, less rapid during the diastole, when the tadpole was placed out of water. The blood, which flowed through an opening made in the two large vessels of the tail, exhibited the same colour and aptitude to coagulate.

EXPERIMENT CLX.

Thirty-fifth day.

The two large vessels of the tail in their whole length, had the shape of two cones; but the space, included between the origin of the branches, was of a cylindrical figure. Having now more particularly attended to the heart and aorta, I found that the first preserved, during the systole, a portion of red blood when the tadpole was allowed to remain in water; but, if the animal was withdrawn from this element, the redness diminished, and at last entirely disappeared; so that it would have been difficult to distinguish this viscus unless its motion had continued. The disappearance of the red colour was not occasioned by a total want of blood; for it could be discovered

discovered in the ventricle by the help of a microscope, but in so very small a quantity, and consequently in such a state of rarefaction, as to be invisible to the naked eye.

EXPERIMENT CLXI.

Fortieth day.

The blood having a very rapid motion in the two large vessels of the tail, I endeavoured to institute a comparative estimate between the velocity of this fluid, and that in the mesenteric trunk of full-grown frogs. I employed the same lens as usual; but after the greatest attention I could discover no sensible difference between the circulation in the vessels of these two animals. The tadpoles had now acquired the size of a small pea,

I numbered for the space of a minute the pulsations of the heart in tadpoles and frogs: in the first they were from sixty to sixty-five, in the second, from forty to forty-nine. The strength, in neither of the animals, had been in the least diminished.

EXPERIMENT CLXII.

Fiftieth day.

Although in none of the vessels was the blood wholly without colour, yet in those of frogs it was of a darker and more florid red.

EXPERIMENT CLXIII.

The same day.

The colour of the blood in frogs was rendered paler by the want of food (Sect. I.) Anxious to ascertain if the same phænomena would occur in the tadpole, I deprived a certain number of these animals of food for fifteen days, and the colour of the globules was so much diminished as not to be seen in the small ramifications. I allowed the same tadpoles to fast during other fifteen days; at which period the two large vessels of the tail scarcely exhibited, in their largest diameter, a reddish cloud; and in the other ramifications the globules were perfectly transparent. Such was the leanness of these animalcula that they did not exceed above half their former size.

EXPERIMENT CLXIV.

Sixty-second day.

The rudiments of the posterior extremities were now observed with their small toes strewed over with vessels, nearly in the same manner as the chick in ovo. The size of the tail had increased, so that the two large vessels were not discernible upon its superior part; we could only observe the lateral branches, where the sides of the tail were less opaque. The number of these branches were incalculable, and the blood in them was almost equally red as in the full grown animals.

EXPERIMENT CLXV.

Seventy-first day.

The anterior extremities were now likewise evolved. The tail, instead of increasing, began to shrivel, and was so disfigured, that the greatest number of its vessels were already obliterated. The blood was of the same colour as in full grown animals.

EXPERIMENT CLXVI.

Eightieth day.

Whilst the tail in several tadpoles was either wholly or partially shrivelled, the greatest number of these animalcula were transformed into frogs, which, not being able to live continually in water, sought to escape by means of their limbs, which had now attained to their full growth.

The mesenteric and pulmonary blood was equally florid as that in older frogs.

DISSERTATION II.

ON THE PHÆNOMENA OF THE CIRCULATION THROUGHOUT THE VASCULAR SYSTEM.

ANALYTICAL VIEW

Of the results from the experiments in the first dissertation.

FIRST RESULT.

WE have certainly reason to be astonished, at the many different opinions, that have prevailed, respecting the changes, which the heart undergoes, during its contraction and dilatation. Ocular evidence, however, will not permit us to entertain the least doubt that in salamanders, lizards, frogs, toads, &c. it is shortened during the systole, and lengthened in the diastole. (Exp. I. II.) It should even seem that this is a general law of nature, at least, among that innumerable class of animals, in which the heart has a conical or pyramidal figure.

SECOND RESULT.

Another general law is, that the pericardium, when in a healthy state, always contains a greater or less quantity of lymph. (Exp. II.)*.

THIRD RESULT.

Haller affirmed, that the heart was almost completely emptied in every contraction; and this opinion he supported by the following reasons: 1, That any remaining portion of blood would counteract, by its continual stimulus, the renewal of the diastole: 2, Because it is an established fact, that the heart of frogs and of the chick in ovo, assumes upon each systole a pale colour, proceeding, no doubt, from the expulsion of the red globules, since otherwise they must have been perceived through the transparent mem-

* All the surfaces of the internal cavities are moistened with a similar fluid, which serves to lubricate the parts and facilitate their motions. The liquor *pericardii* is doubtless absorbed and secreted in the same manner as that contained in the other cavities of the body.

It seems, indeed, an universal law, that all secreted fluids which have no outlets, are occasionally resumed into the course of the circulation, as the aqueous humour of the eye, liquor of the thorax, abdomen, vaginal tunic of the testicles, &c. &c. *R. H.*

branes of this organ. My experiments upon the heart of grey and green lizards, and the chick in ovo, coincide with those of the physiologist of Berne: (Exp. III. CXV.) but those, on the contrary, relative to salamanders and green frogs, present results very different. The heart of these animals, if their strength was not wholly exhausted, preserved always a reddish tint, (Exp. III. XXV.) which could not be the effect of a small portion of blood, since on opening the sides of this viscus, towards the end of the systole, a very considerable quantity was effused. (Exp. IV.) The same red colour also appeared in the heart of tadpoles, excepting only that it was less florid during the systole than the diastole, (Exp. CLII. CLVII. CLX.) Although from its smallness, the heart of these animals could not be opened, yet such was the transparency of its membranes, that we observed this viscus filled, during every diastole, with a small cloud of red globules, which it partly expelled on the return of each contraction. (Exp. CLII. CLVII. CLX.)

Since, then, it cannot be affirmed, generally, that a complete depletion of the heart takes place during its systole, we cannot agree with Haller, that the remaining quantity of blood produces

that

that continual stimulus which he conjectured. Besides, upon this principle, we would be led to suppose from the greater comparative irritability of young than full grown animals, that this organ, in the former, should retain a less quantity of red blood; on the contrary, however, the heart of tadpoles always retained some drops, whilst not a single globule was perceivable in that of frogs. Thus it happens, that in physics, theories the most plausible, often lead to error, when unsupported by accurate experiment and observation.

FOURTH RESULT.

Most physiologists have concluded that the arteries, during the systole and diastole, were alike full, and distributed the same quantity of blood. Of this fact, I was fully assured previously to my having opened any of these vessels, (Exp. XII. XIV. XV. XXI. XXVI. XLV. CXXXIII. CLVII.) For, although the thickness of the coats in the aortal trunk of frogs and lizards, precluded an accurate view of the circulation, yet in the salamander this vessel afforded an exception, becoming almost entirely empty during each systole; so, at least, we were led to conjecture, not only from its extreme paleness, but because, from an opening made in this vessel during its contraction, not a single red globule escaped. This circumstance, however, only occurred when the animal had been previously enfeebled; for while its strength continued unimpaired, the aorta always retained in its systole a small quantity of blood. (Exp. V. VI. VII. VIII. IX. X.)

It must not, however, be supposed that a complete depletion took place in the aorta, at the time of its contraction: it seemed, on the contrary, probable, from its sides never coming into actual contact, that even then it was filled with that fine lymph which serves as a vehicle to the red globules; the existence of this fluid, as will afterwards appear, cannot be doubted; and which in the opinion of Haller, supplied the place of the blood in frogs enfeebled by a long want of sustenance.

FIFTH RESULT.

From theory we were led to suppose, that the last column of blood propelled by the ventricles, had a greater velocity than the proceeding current, and that the motion of the arterial fluid was more rapid during the systole than the diastole of the heart; but this supposed inequality of momentum did not agree with the uniformity

observed

observed by some physiologists in the mesenteric arteries of frogs.

It was only necessary, in order to resolve this question, that we should examine the arteries throughout their extent. The circulation in the great trunk of the aorta was interrupted and unequal; it stopped upon every diastole, and resumed its original motion in the following systole. The same appearances occurred in the superior portion of the descending aorta, but near the origin of the tail the irregularities in the motion of the blood diminished by degrees, and even disappeared altogether towards the base of this extremity, excepting only that the momentum was greatest during the contraction of the heart. This inequality of motion did not take place in the pulmonary, mesenteric, and other middle-sized arteries. These three periods of momentary inaction, of unequal and uniform momentum in the arterial circulation, were alike evident in salamanders, water, and land-frogs, grey and green lizards, (Exp. IX. X. XII. XIII. XIV. XV. XIX. XXIV. XLII. XLV.)

It ought, however, to be remarked, that in the middle-sized arteries, the blood circulated only with an uniform velocity, when the strength of the

the animal was unimpaired; for, in proportion as it became exhausted, the blood moved with less rapidity, during the diastole than the systole of the heart (Exp. XLII. XLV). This alteration in the circulation seemed to be occasioned by the inertia produced in the greatest number of the small vessels from the weakness of the animal. Thus, then, as the column of blood most remote from the heart could not circulate with the same facility as before, it was exceeded in velocity by that which had received the last impulse from the ventricle: it is yet, however, sufficiently probable that this inequality of motion might have proceeded from any cause impeding the free action of the heart (Exp. XVIII. XXVII.)

SIXTH RESULT.

Although it seemed probable, that all the animals were subjected to these three periodical changes in the circulation, it must not be supposed they were equally so through every stage of their existence. In proportion to their age the arterial blood presented new phænomena, of which a brief analysis shall be given from the experiments made upon the chick and tadpole. During the two first days of incubation, an interrupted

terrupted motion was evident in the arterial fluid, which after having circulated during the systole, through a very small space, stopped in the diastole, and resumed its course upon the following contraction (Exp. CXV). Although from the second to the third day it observed the same periods of motion and rest, yet its course was more extended (Exp. CXVI.)

On the third day, when its inaction ceased, it flowed without interruption, less rapidly, however, during the diastole, than the systole (Exp. CXVII.) twelve hours afterwards its velocity augmented upon every contraction (Exp. CXXII.) and on the fifth day, it was uniform through almost the whole arterial system, (Exp. CXXVII. CXXVIII). From this time the circulation gradually increased in velocity, to the termination of the incubation (Exp. CXLIII.)

This equal momentum was maintained throughout the arterial system, with the exception of some large and small vessels, wherein the blood flowed with more or less rapidity, according as the heart contracted or dilated (Exp. CXXXIII. CXL.)

The

The same irregularities affected the circulation in tadpoles, but they succeeded each other more slowly. On the fifth day, some signs of motion were perceived in the auricle and ventricle; and on the sixth, also, a beginning circulation in the vessels (Exp. CXLVIII.) The blood flowed and stagnated successively during every systole and diastole (Exp. CXLIX.)

The circulation increased till the tenth day (CLI.) but after the twelfth it no more exhibited any alternation of motion and rest, although its course was more rapid during the systole than the diastole (CLII.)

The acceleration in the course of the blood during the systole, was scarcely perceivable on the fourteenth day (CLIII.) and entirely ceased on the eighteenth, when the circulation was carried on with equal quickness, at least in the largest vessels (Exp. CLV.) During the following days, the motion of the blood became more and more rapid (CLVIII.) so that on the fortieth it had already acquired the same velocity as in the mesenteric artery of frogs, although the size of the tadpole did not exceed that of a small pea (CLXI.)

Whatever

Whatever might be the age of the tadpole, the blood circulated by jets, stagnating for a moment upon every diastole in the aortal trunk (Exp. CLVII. CLIX.); and this phænomenon was the more unexpected, as the pulsation of the heart in these animals amounted, during one minute, from sixty to sixty-five, whilst in that of frogs, during the same period, they never rose above fifty (CXLI.)

We cannot call in question, that these different periodical changes of the circulation in the chick and tadpole, proceeded from the action of the heart, which increasing every day in size and activity, communicated to the blood a greater and more rapid impulse; and as the most intimate analogy subsists between these and other cold and warm-blooded animals, we may hence conclude, that in general, the circulation proceeds in the same manner during the evolution and growth of their organs.

SEVENTH RESULT.

The pulsations of the arteries are commonly attributed (*) to the re-action which the blood, propelled by the contraction of the heart, pro-

(*) See the fourth dissertation.

duces

duces on their sides; but this fluid cannot circulate in an instant through the whole arterial canal, whence it results, that the pulsations must occur in succession, beginning in that portion of the artery nearest the heart, from its having first received the impulse communicated by this organ to the blood, and afterwards proceeding to the anterior and more distant parts; but although it is evident this successive motion must take place, it cannot be perceived, as the circulation is carried on with such astonishing celerity, that at the very moment when the heart contracts, the aorta and the whole of the arterial system seem to beat at one and the same time (Exp. XVI. XVII. XLV.)

EIGHTH RESULT.

When we reflect upon the organization of the vascular system (II), the innumerable windings through which the blood must flow, from the heart to the extremities, and the multitude of obstacles opposed to its course, we should be led at first to suppose, that it ought to circulate with extreme languor in the ultimate arterial ramifications. Such, besides, is the nature of the blood, that it can only be preserved in a state of fluidity by the motion with which it is continually

tinually agitated, and the moving forces must be consumed in proportion to the attraction of cohesion, not only between the globules themselves, but also by that which prevails between these molecules and the sides of the vessels.

To these causes may be added the greater capacity of the dividing branches, relatively to that of the artery itself: for although the diameters of the vessels diminish in proportion as they divide, yet the sum of the capacity of all the branches considerably exceed that of the trunks; an observation which has been already verified in man, and several other animals, and which I found equally to hold in those I have examined (Exp. XXXIII)*. Thus the blood in flowing from the aorta to the trunks, from the trunks to the branches, and from the branches to the ramifications, will move in a canal, the successive augmentation of which must diminish its velocity, like those fluids which lose their momentum in flowing out of a small into a large tube. In the dilated portions

* Anatomical observations evince not only the universality of this law, but, moreover, that the sides of small vessels are much thicker in proportion to their capacities, than the sides of trunks compared with their diameters. *R. H.*

tions of the artery the blood underwent some abatement of motion, which upon emerging, it immediately recovered (Exp. XX.)

To this augmentation of diameter may be super-added the friction of the globules against the sides of the arteries, which ought to retard the velocity of the circulation in proportion, 1, To the momentum of the blood itself, since the more rapid the course of the globules, the greater must be the friction from the increased number that will come into contact with the sides of the vessels. 2, To the length and straitness of the arteries, the one presenting a more extended surface to the action of these molecules, the other diminishing the number which circulated without any obstacle, in the wider part of the canal. 3, In short to the multiplicity of sinuosities and angles which, by either producing a change in its direction, or an increase of friction will considerably retard the velocity of the circulation.

All these causes deduced from the science of Hydraulics, and arbitrarily applied to animated beings, have induced many physicians to believe that the velocity of the circulation near the heart, is in a direct ratio to its languor in the ultimate

ultimate arterial ramifications. Haller, fully convinced that we ought not to reason by analogy from mechanical laws to those of the living system, determined, before establishing any theory, to have recourse to direct experiment and observation; and he discovered that the circulation actually experienced a retardation in the small capillary arteries; but that there was no relation between this retardation and the supposed obstacles that we have detailed. He found that the momentum of the blood was nearly equal in the large and small mesenteric vessels of frogs; hence he concluded, that the circulation ought not to be less rapid in the arterial branches than in those of the veins, since the venous receives its impulsion from the arterial fluid. His method of examination did not, indeed, enable him to trace the whole distribution of the mesenteric vessels, which in these animals are extended to the intestines, far less could he compare the motion of the blood in the large and small arteries of warm-blooded animals, had he even been acquainted with those in which the circulation is evident; so that it is from analogy alone, he was led to believe, that they must be subjected to the same laws he had discovered to prevail in cold-blooded animals.

The readiness with which I could examine the whole vascular system in these two classes of animals, enabled me to observe whether the blood experienced any retardation in the numerous flexures and convolutions of the arteries, as well as the precise degree of this retardation; and thus to throw some light upon a very important and obscure point in physiology.

I did not immediately perceive any difference of momentum betwixt the large and middle-sized arteries; when, however, I attentively examined these portions of the large arterial vessels in which the blood abated at each diastole, (Result Fifth) it appeared to circulate more rapidly during every systole than in the middle-sized arteries, whilst, in the latter, it preserved an uniform rapidity during both the systole and diastole (Ibid.) Thus it seemed, that although the blood in the large arteries possessed a greater momentum than in the middle-sized during each contraction, yet that these in their turn experienced the same superiority of motion over the former during every dilatation of the heart. The blood appeared, indeed, to circulate less rapidly through the large artery in the tail of tadpoles, in proportion as it advanced towards its extremity (Exp. CLV.)

I did

I did not find that the blood, in passing out of the middle-sized arteries into their branches, experienced the least retardation from any difference in the capacity of these vessels; or the numerous angles which they formed with one another (Exp. XXXIII.); neither did the mode of the circulation, whether languid or strong, oscillatory or intermittent; (Exp. XVIII. XXI. XXXIV.) appear to be at all affected by the multiplicity of natural and artificial curvatures, or the flexures and convolutions made by the different ramifications (Exp. XXXVI. XXXVII. XXXVIII. XXXIX. XLVIII. LI. LXI. CXXI. CXXVII.) When the strength of the animal was not impaired, the blood in the small arteries moved very rapidly (Exp. XLIX. L. LV. LVI. LXIII. LXXVI. LXXVII. CXXVII. CXXVIII. CXXXII. CXLIII.) and with nearly an equal velocity (Exp. XLIX. L. LV. LXIII. LXXXII. LII. LXXVI.); but when, on the contrary, it had been exhausted, or in an unhealthy state, the circulation was carried on with the same celerity in the middle-sized arteries, whilst it began to abate in the small arterial ramifications, and stopped sooner or later in proportion to their distance from the heart (Exp. XXI. LXXVI. LXXVII. LXXVIII. LXXIX.) Besides, we ought to take into account that the small arteries which are distributed to the moist surfaces of the internal parts, retain longer their original motion (Exp. LVI. LXII. LXXVI. LXXVII.)

The united results of these facts display, in a striking point of view, the true motion of the blood from the origin to the termination of the arteries, which was hitherto only conjectural and subject to frequent disputes, from the want of a sufficient number of experiments.

These facts, besides, confirm the sage maxim of Haller, respecting the caution with which we ought to apply mechanical principles to the animated system; for, in fact, if the animal machine be strictly subject to Hydraulic laws, why do they not produce the same effects in the vascular system as in common tubes. Whilst, however, we acknowledge that these laws must exert an influence upon the phænomena of the circulation, we contend that their power is counterbalanced by opposite causes, inherent in the sanguiferous system (III.)

NINTH RESULT.

Do the red globules, in flowing through the labyrinth of arterial ramifications, or from the friction against the sides of the vessels, experience

rience any rotatory or intestine motion? Several modern physiologists have believed that such a motion exists, in opposition to the experiments of Haller, which I have so often confirmed in cold and warm-blooded animals. Let the reader, however, conceive some small pieces of wood swimming in a canal, with a rapidity equal to the current, and he will be able to form an accurate idea of the motion of the globules carried along by the lymph, which serves them for a vehicle (Exp. XXXIV. XLVI. XLVII. XLVIII. CVI. CXLIII.)

TENTH RESULT.

It has been already observed, that the acceleration in the motion of the blood, produced by the systole of the heart, was evident in the middle-sized arteries when the strength of the animal became somewhat impaired (Result Fifth); a fact which sufficiently proves the influence exercised by the heart upon this order of vessels, and which is extended even to their ultimate ramifications. This was the result not only of Haller's experiments, but of those which I made upon the small arteries of salamanders; in which the velocity of the blood abated, during the diastole, and augmented during the systole of the heart (Exp. LVI. LXIII.)

Whether the circulation in warm-blooded animals be regulated by the same law, is a question that could hitherto only be resolved by analogy: from actual observation, however, I have discovered that the pulsation of the arteries, which can only proceed from the contraction of the heart, is evident in the small ramifications; the capacity of which scarcely equals the sixth part of a line, and that the blood issued from an opening made in these vessels with greater force during the systole than the diastole of the heart. I have myself constantly observed in the chick, this direct action of the heart, which, by its contractile force, re-animated or accelerated the momentum of the blood in the smallest arterial ramifications, (Exp. CXVI. CXVII. CXVIII. CXIX. CXXI. CXXII. CXXVI. CXXVII. CXXIII. CXXIX. CXXXII. CXXXVII. CXXXVIII.)

ELEVENTH RESULT.

If it be incontrovertible, that the arterial extremities are acted upon by the contraction of the heart, is it equally true that its effects are extended to the origin of the venous ramifications? The celebrated Hales has observed that the motion of the blood in the small pulmonary veins of a frog, augmented during every systole of the heart: but Haller was of opinion, after several experiments,

riments, that this accelerated momentum ought rather to be attributed to some irregularities in the circulation, which, after having been a long time suspended, was frequently restored with the strength of the animal. I admit that the restoration of the circulation must be subject to the greatest illusion, and that besides, as has been already observed in several animals, its acceleration from the contraction of the heart is almost wholly confined to the arterial system. Contrary observations have, however, compelled me to conclude, that the velocity of the venous fluid is redoubled during the systole, and abates during the diastole of the heart in salamanders, land frogs, the chick in ovo, and the tadpole; not only in one or two, but in a very great number of small veins, whether the circulation be carried on in a very rapid or languid manner (Exp. LIV. LXXIV. CXXI. CXXX. CXXXI. CXXXIV. CXXXVI. CXLIV. CXLIX. CL. CLI. CLII. CLIX.)

TWELFTH RESULT.

The union of the arterial and venous vessels is effected in different ways. The capacities of the arteries, at their junction with the veins, were extremely various. Whilst some admitted four or five red globules (Exp. CXVIII.)

 others

others only received one at a time (XLIX. L. LI. LVI. LXIV. LXXIII. CXVII. CXXX.) Sometimes, particularly in the chick, the arteries, upon being reflected back towards the heart, very commonly gave rise to an equal number of venous branches (Exp. CXVI. CXXI. CXXXV. CXXXVI. CXXXVIII. CXXVI.) At other times, from their subdivisions were produced a very complicated net-work, which might be regarded as the intermediate point of communication between the arteries and veins (Exp. LI. LXIII.) and from this tissue of small vessels a great nunber of veins proceeded towards the heart in the same direction with the arterial branches, from which they originated (Exp. LII.) Sometimes several arteries terminated in a single vein (Exp. LII.) sometimes they sunk into the substance of the organs and disappeared (Exp. XLVIII. LXII.) Some of them passed into a large vessel, which, being situated at an equal distance from the heart, left us in doubt whether it was an artery or a vein (Exp. CXVI.); others gave rise near the heart, to a small vein which returned towards this viscus, whilst the arterial trunk continued its course to the extremities (Exp. CXI.); or they were subdivided into two branches, one of which preserved the character of an artery, and the

other

other performed the office of a vein (Exp. LIV.) The velocity of the blood was for the most part equal in the termination of the arteries, and the orifices of the nascent veins (Exp. XLIX. L. LXIII. CXXV.)

THIRTEENTH RESULT.

Physiologists have been led, rather from theory than ocular demonstration, to admit that the momentum of the venous fluid increases in proportion as it approaches the heart. According to them the sum of the veins may be compared to a large concave cone, the base of which corresponds to the capillary extremities, and the apex to the auricles of the heart. But, as the contraction of the canals must augment the velocity of the fluids, the blood ought to circulate slower at the base than the summit of the venous system.

We are here again indebted to the philosophic scepticism of Haller, who, not satisfied with the analogy drawn from mechanical principles, had recourse to direct observation and experiment; and if he has not entirely drawn aside the veil, he has at least rouzed the curiosity of others, and pointed out the true path which might conduct them to the object of his research. His observations observation were limited to two veins; but a general conclusion ought only to be built upon a concurrence of several facts agreeing between themselves, and subject to the same relations; hence, it appeared to me necessary to examine a great number of vessels, the course of which I have followed from their union with the arteries to the heart.

The results of my experiments agree with those of Haller in this, that, excepting at their points of junction with the arteries, in all the veins, whether small, middle-sized, or large, the circulation was more rapid in proportion as the vessels augmented in diameter, and received the blood from a greater number of branches (Exp. LI. LIII. LXII. LIII. LIV. XCI. XCV. XCVI. CXXXI. CXXVII. CXXVIII. CXXIX. CXXXV. CXXXVI. CXXXVII. CXXXVIII. CLV.)

Among these vessels must not be included the two *cavæ* of the salamander, in which the blood flowed with the same velocity as in the middle-sized veins (Exp. CX); but it is not difficult to account for this single exception. The blood forcibly penetrated into the auricle, during its dilatation; whilst upon the contraction it was driven back towards the *venæ cavæ* (Exp. CX.); from

which

which resulted a flux and reflux, that obstructed in the large trunks the velocity of the circulation.

We can only attribute this accelerated momentum of the blood in flowing from the small to the middle-sized, and from the middle-sized to the large veins, to the progressive diminution of their capacities, from the extremities to the heart. Two facts in particular confirmed me in this opinion. 1. If these vessels were naturally, or by accident of an unequal capacity; that is, less capacious in one portion than another, the blood redoubled its velocity, upon circulating through this strait portion; but no sooner had it emerged, than it recovered its usual momentum (Exp. XXXV. CIV.) 2. The circulation was carried on with the same celerity in the veins, which, passing through a certain space without receiving any branches, were of a cylindrical form, and consequently of an equal diameter (Exp. LXXXVII. CXVIII. CXXXVIII.)

It was with difficulty we could distinguish the proportional difference of momentum between the small and the large veins. All my experiments, however, led me to conclude, that, in the first, the blood circulated three times slower than in the second. It would hence appear, that this boasted

boasted law of Hydraulics* has no share in the acceleration of the venous fluid, else how can it be reconciled with the inequality in the circulation which prevails between the base and the apex of the supposed cone of veins, and which must be counterbalanced by some unknown cause, more powerful than the sinuosities, the angles, the flexures and convolutions of the vessels which produce no change in the circulation? (Exp. LI. LXI. XCI. XCVIII. CXXIII. CXXIV. CXXVII. CXXVIII.)

FOURTEENTH RESULT.

Haller remarked that when two veins of a very unequal capacity anastomosed, the force of the

* Reasoning by analogy from mechanical laws is, indeed, scarcely applicable to a physiological subject; particularly to the complex actions of the living system. We cannot, therefore, be surprised that the amount of the retardation experienced by the blood in the small vessels, does not exactly correspond with mathematical calculation. As, however, it is demonstrable that the sum of the areæ of the branches always exceeds the area of the trunk from which they proceed, so it should seem to follow, that the blood must circulate more slowly in the small vascular ramifications than in the trunks themselves; unless when the former may be stimulated into increased action by the presence of any unusual irritation. *R. H.*

circulation in the large vein opposed the influx of the blood from the small vessel. These anastomoses between large and very small veins, according to him, indeed, seldom occurred; as the most subtile ramifications united into canals somewhat larger, which again receiving in their course other ramifications of a more considerable capacity, thus established a kind of gradation which gave to the blood in the largest branches a force sufficient to penetrate into the trunks, whatever might be the resistance opposed to its course.

Such is, doubtless, the order established by nature in the organization of the vascular system; for, in the same manner that the venous fluid, before arriving at the large trunks, flows through an infinite number of ramifications whose capacities augment as they approach towards the heart, so the arterial blood reaches not the ultimate ramifications until it has circulated through all the arterial canals, which become smaller in proportion to the frequency of their subdivisions. This mechanism is particularly beautiful in the mesentery and intestines of several animals; often, however, I have witnessed the circulation carried on in a directly opposite manner, although the course of the blood was not in the smallest degree disordered. Thus many capillary ramifications anastomosed at different angles with the venous trunks, without in the least impeding the usual velocity of the blood, (Exp. LXIV. CXI. CXII. CXIII. CXIV. CXXXIX.) hence we should be inclined to believe, that in the instances cited by Haller, the blood must have experienced some obstacles in flowing out of the branches into the trunks from the diseased state of the animal; more particularly as he mentions in his relation of these experiments, that the circulation had been subject to the greatest irregularities.

FIFTEENTH RESULT.

Although Haller conceived that the effect produced by the systole of the heart extended not to the venous system (Result XI.) he was nevertheless persuaded, in opposition to the sentiments of several authors, that the circulation of the blood depended almost entirely upon the action of this viscus; and this opinion he principally supported from the example of persons drowned, and animals in a state of asphyxia, in whom it was only necessary to excite the action of the heart in order to restore the motion of the fluids after it had been suspended for several hours.

My

My experiments appear to establish this truth in such a striking point of view, as cannot, I think, fail to convince the most sceptical reader. I shall, however, first endeavour to demonstrate the insufficiency of those causes which have been usually associated with the power of the heart, and which have been supposed more or less numerous in the opinion of different physiologists.

The contraction of the arteries, the attraction of the capillary vessels, a *vibratory* or *oscillatory* action in the vascular coats arising from the stimulus of the blood, and, in short, the air contained in the arteries and veins rarefied by the heat of this fluid, have each in their turns been supposed powerfully to second the action of the heart.

Experiments have proved the fallacy of these different hypotheses: for, if it be true that the vessels originally contain any species of air to which the blood owes part of its momentum, this air should appear under the form of small bubbles which could not entirely have eluded the sight; the power of the microscope I employed, being so great as to have enabled me to distinguish these bubbles, had they even been a fiftieth part smaller than the red globules. In none of my experiments, however, was the least appearance of these aeriform atoms discoverable, excepting when the vessels had suffered any lesion, in which case they were found to contain a very great number that might be increased or diminished at pleasure, by the employment of a more or less powerful stimulus (Exp. LXXXVIII. CIV. CX. CXXVIII. CXLII.) but the casual existence of these molecules, far from augmenting, served, in fact, to diminish the velocity of the blood as it reached the small vessels (Exp. LXXXVIII. CX.) In fine, among cold-blooded animals, the want of heat required by this hypothesis preventing the rarefaction of the air-bubbles, allowing they were really present, should either wholly impede the circulation, or, at least, render it extremely languid: a conclusion which is altogether repugnant to experience.

We must, at least, allow the praise of ingenuity to the hypothesis of attraction and oscillatory motion; but if the vessels really experienced this alternation of contraction and dilatation and an accelerated momentum, these phænomena should be evident; nevertheless, the results of *all my observations* tend to establish a complete *inertia* in the coats of the capillary branches,

branches, and a retardation rather than an augmentation of velocity in the circulation (Exp. LII. LXXVI.)

I have likewise been taught by the evidence of my senses, that the course of the blood is independent of the contraction of the arteries, since in several animals it was only evident in the largest trunks (Exp. V. VI. XVI. XXVII. XXIX. LXII. XLIII.) and as in embryos wherein the circulation is apparent, we perceived no appearance of contraction or dilatation throughout the vascular system (Exp. *on the chick at the commencement of incubation.*)

The insufficiency of these theories being demonstrated, it is easy to prove that the circulation of the blood depends solely upon the action of the heart*: such is the immediate consequence deducible

* Since the discovery of Harvey, several writers as well as our author have ascribed the whole of the circulation to the action of the heart alone; but, although the principal causes which propel the blood be unquestionably the alternate systole of this organ and the contractions of the larger arteries, yet these of themselves would be insufficient to explain the transmission of this fluid throughout the sanguiferous vessels, unless assisted by

deducible from the accelerated momentum of the venous fluid during every contraction of this viscus (Result XI.); because such an acceleration could not occur unless the action of the heart communicated the momentum to the venous as well as the arterial fluid. This truth

by some inherent power in the system capable of counteracting the numerous causes opposed to its course. A variety of facts might, were it necessary, be adduced to demonstrate that the circulation of the fluids is wholly inexplicable upon the hypothesis that the action of the heart is the sole cause of the circulation: a proposition neither founded upon the observations of others nor deducible from our author's own experiments; by which it appears that the blood continued to flow with uniform quickness and regularity in vessels, not only after all communication between them and the heart had been intercepted, but also in the arterial and venous systems of some animals several days after the complete destruction of that viscus. These, as well as many other phænomena of the circulation hitherto obscure, seem to receive a satisfactory elucidation from the laws of irritability as now understood; since if we admit this principle to be an essential attribute of animated bodies, subject to successive expenditure and reproduction, and that the effects produced upon the living system by the action of stimuli are in a compound ratio of the degree of irritability in the fibre and the intensity of the exciting power, we shall not only be enabled to solve the alternate contractions truth is farther corroborated by the following phænomena. Sometimes, in the most vigorous animals, the pulsation of the heart ceased suddenly for some minutes when the circulation was suspended; but its contractions were no sooner renewed than the blood recovered its usual motion (Exp. VI.)

When the heart was compressed in such a manner as to impede the freedom of its action, the circulation abated and even ceased entirely upon increasing the compression (Exp. XXII. XXIII. LXXX. LXXXI. LXXXII. LXXXIII.)

When we removed the ligature which had been a long time applied to the aortal trunk, and permitted the heart to exercise its free action, the blood immediately resumed its original momentum (Exp. LXXXIV. LXXXV. LXXXVI.)

tractions of the heart itself by the stimulus of the blood acting upon the accumulated excitability of that organ, but likewise illustrate the momentum of this fluid in the smallest vessels, and why it does not experience a retardation in an exact mathematical proportion to the various obstacles opposed to its course, as well as many other facts relative to the circulation, which neither the mere impulsion of the heart and large arteries *a tergo*, nor the *vis percussionis* of Borelli seem fully adequate to explain.

R. H.

These facts perfectly corresponded in cold and warm-blooded animals (Result VI.) During the early period of incubation, the heart of the chick was very small, and from its want of solidity it remained nearly inactive. Its motion scarcely continued a quarter of an hour, and the last pulsation was instantly followed by a complete stagnation in the circulation (Exp. CXV.)

The heart afterwards increasing in volume and activity, the blood circulated with greater force; and when the incubation was nearly completed it flowed with extreme rapidity (Exp. CXVII. CXXIII. CXXIV. CXXVI. CXXVII. CXXX. CXLIII.)

When the heart ceased to beat, the circulation was immediately arrested; when it recovered its motion the blood was re-animated likewise; and upon suspending or renewing the action of this muscle, the blood discontinued or recovered its usual momentum (Exp. CXVIII. CXIX. CXX. CXXI.)

When the pulsations of the heart became less frequent, the blood flowed with greater languor; was even arrested at the commencement of the diastole, and resumed its motion only with the following contraction (Exp. CXXI.) It would be difficult to afford stronger evidence that the heart is the sole and only moving power of the circulation, (IV.)

Another fact worthy of remark is, that the moment the heart ceased to beat, the venous was arrested before the arterial fluid *; and that after the re-establishment of the heart's motion, the circulation began in the arterial sooner than in the venous vessels (Exp. LXXX. LXXXII. CXVIII. CXXI.) These phænomena admit of an easy solution; the veins receiving after the arteries the impulsion from the heart, were the first to lose the motion thus communicated to them. To this fact may be added the acceleration of the venous fluid (Result Thirteenth) which abated with the cause which produced it, that is the systole of the heart.

SIXTEENTH RESULT.

Although the coats of the large veins were thinner than those of the large arteries (Exp. CIX.) yet, in the middle-sized veins and arte-

* This conclusion, the reader will observe, is in direct opposition to the evidence furnished by the experiments referred to in the text, *R. H.*

ries, they appeared to be of the same thickness at least; in all my experiments the blood was equally evident in both these species of vessels. In the salamander, the transparency of the middle-sized and small vessels was so great, that the blood did not appear to be contained in a real canal; and in some of the vessels we even perceived the course of the circulation without the assistance of a microscope (Exp. LXXXVII.) This, I presume, has not been observed in any other animal, since the discovery of Harvey: yet, it was evident in the trunk of the aorta (Exp. V.) from the transparency, and whiteness of its coats.

SEVENTEENTH RESULT.

The veins and arteries, considered in their whole extent, were of a conical form; but the branches, taken singly, had a cylindrical figure (XI. XVIII. XXXVIII. XC. XCVI. CXVIII, CLX.): some of them, however, were throughout of an equal capacity (Exp. LXXXVII. CX.)

EIGHTEENTH RESULT.

The veins, in general, were of a capacity larger than the accompanying arteries (Exp. XC. XCIII. XCVI.) and much more numerous (Exp.

(Exp. XCVI). In the mesentery of the salamander, the number of the former was double that of the latter (Exp. XCVI.); and it held equally true with respect to the vessels composing the umbilical cord of the chick (Exp. CXVII. CXVIII. &c.) It should then seem, that the veins being supplied with blood by the arteries, its momentum in the first, ought to be less rapid than in the second, upon the principle that they contain a given quantity of this fluid. This, however, is one of those theories which may be overturned by experiment. All my observations prove, that the venous circulated with the same quickness as the arterial fluid in the small and large vessels (Result Twelfth) such as the mesenteric, the pulmonary, the axillary, &c. (Exp. XC. XCIII. XCVI. CLV.)

These results are in direct opposition to the experiments of Haller; but, I employed every precaution in my power to avoid error; and after the most accurate and attentive examination, I cannot agree with that celebrated physiologist, without departing from the truth. The reason of this difference must, doubtless, be imputed to the vessels in my experiments, having been allowed to remain in their natural situation; whilst he examined them after they were separated from the body of the animal; and it has been already noticed in the introduction, how much this last method is subject to allusion. I have then every reason to believe, that the greater celerity observed by Haller, in the venous fluid, must have proceeded from some disorder occasioned by the stretching of the mesentery: which is rendered still more probable by the stagnation and oscillatory motion of the blood, which, according to this author, succeeded each other alternately. The authority, however, of such a respectable observer, as Haller, induced me to make the most cautious and extensive observations, on the animals which had been the subject of his experiments, viz. frogs. When I prepared the mesentery with hooks, the arterial sometimes flowed more rapidly than the venous blood; sometimes the last exceeded the former in velocity; whilst at other times their momentum was equal. But when, on the contrary, I allowed this membrane to remain in its natural position, the circulation was uniform in this double order of vessels* (Exp. XCVII. &c.)

This

* The experiments here related, seem to us only to prove, that in certain circumstances, the difference of momentum in the arterial and venous fluids, may be nearly

This equality of motion was, nevertheless, only present when the circulation was carried on with

nearly equal, but by no means can they be considered as fully establishing the fact in question, as a general law in the living system. Were we to found our estimate of the comparative velocity of the fluids, circulating in the arterial and venous systems, merely on the capacity of this double order of vessels, we should certainly be led to a very different conclusion: for as the sum of the capacities of the veins exceeds, considerably, those of the arteries; so if the rapidity of the blood's motion in the latter, did not exceed in the same proportion that of its return through the former, the equilibrium of the circulation would be destroyed. This reasoning is farther supported by the authority of Dr. Hales, from whose experiments it appears, that the force with which the blood returns to the right ventricle of the heart, by the two *venæ cavæ* is in animals, when at rest, and not agitated with convulsions, only equal to about $\frac{1}{10}$ of the momentum, with which it was propelled by the left ventricle into the aorta. Now although in a question of this nature, no kind of reasoning ought to have weight, when opposed by fair experiment; yet, when we take into consideration the variety of concurrent circumstances which tend to produce a fallacy in our observations, and, moreover, that this conclusion is not only in direct opposition to probable reasoning, but likewise to the experiments of other eminent physiologists, a more enlarged and comprehensive induction seems still necessary to confirm, or invalidate the results of our Author on this subject. *R. H.*

force and rapidity; for, after it began to move by jets, it was difficult to make a comparative estimate of its velocity; far less was it possible to examine the corresponding arteries and veins, because the circulation was not uniformly rapid in all their different portions; thus, it was slower in the mesenteric vessels, than in those of the lungs, and the surface of the palate (Exp. XL. XLI. XCIII). It was the same, for example, in the splenic and hepatic veins, in which the blood exhibited the greatest abatement of its momentum (Exp. CVI. CVII. CVIII.)

NINETEENTH RESULT.

Such was the influence of atmospheric air upon the pulmonary vessels, that it arrested or diminished their momentum, whilst this viscus was rendered, either naturally or artificially empty (Exp. XX. XXXI. XCI.) When an entire depletion of bile occurred, the circulation likewise ceased in the vessels of the gall-bladder (Exp. XLIX. L.)

It was formerly a prevalent opinion, and several physiologists still continue to believe, that the circulation is carried on more rapidly in the lungs than in other organs; and their opinion is principally founded upon this, that the blood, besides the impulsion of the heart, receives an additional momentum from the lungs themselves.

I have endeavoured, by every possible mode of investigation, to throw some light upon this important question. The results have not been uniform in the animals I have examined, or in the different parts of the vascular system. The blood in the salamander flowed more rapidly in the pulmonary than in the mesenteric, or axillary vessels (Exp. XL. XCIII. XCVII.); its motion, however, in the first, was as great as in the cutaneous vessels, and those of the *velum palati* (Exp. XLI. LXIII. XCIV.) But in the vascular system of water and land frogs, the circulation in every experiment was uniformly equal. Haller had made the same observation upon toads.

TWENTIETH RESULT.

From these experiments we must already be convinced, that the red globules circulate with equal velocity, excepting that round the sides of the vessels, their momentum is less than in the axis: as water runs with greater rapidity in the middle than at the sides of a canal. This theory

theory is confirmed by all my observations, whether the motion of the blood was carried on in an uniform, irregular, oscillatory, or retrograde manner (Exp. XCIX. C. CI. CXXXIV.)

TWENTY-FIRST RESULT.

The arterial and venous blood differ neither in density nor colour (Exp. XCI. XCVI. CXXII.) and after being drawn from the vessels, they exhibit the same fluidity, and the same aptitude to coagulate (Exp. XCII. CLIX.) provided they have been furnished by vessels of an equal capacity. When, however, the arterial was larger than the venous branch, or *vice versa*, the blood exhibited, in the first case, a much darker red than in the second (Exp. XCI.)

TWENTY-SECOND RESULT.

It is a generally received opinion, that the blood which is at first yellow, assumes a brownish colour, which is afterwards changed into a florid purple, in proportion as the animal advances in age.

It is likewise believed, that the blood inclines more or less towards yellow, as its quantity is diminished, or as it is arrested, or retarded in its

course,

course, either from want of food, or in consequence of a hæmorrhage.

These two questions discussed by Malphighi, Senac, Haller, &c. demanded, on my part, the most accurate investigation; and I have accordingly attended with strictness and impartiality, to the labours of these illustrious men, and with the most ardent desire to ascertain how far their opinions accorded with the actual phænomena observed in the living system. For, in examining the most generally received opinions, I have always rejected arguments drawn from authority, and endeavoured only to ascertain the truth of the facts upon which they are founded.

The blood of the chick, during the first days of incubation exhibited all the colours already mentioned; but they were visible at the same time: for when this fluid appeared yellow in the small vessels, it had a brownish tint in the middle-sized; was of a pale red in the large trunks, and more particularly in the heart (Exp. CXV.): anterior to the fortieth hour, neither vessels, nor circulation were distinguishable. This mixture of colours gave rise in my mind to the most confirmed suspicions, respecting the truth of the foregoing theories: For if yellow

were

were the original colour of the blood, why was it not evident in the extremities of the vessels? or why, more particularly was its colour different in the heart, the trunk, and the branches? These different colours appeared to be the effect of some optical illusion, produced, probably by the yolk of the egg being seen at the same time with the vessels: for although the blood was essentially red, it might yet partake of the colour of the yolk in those branches, wherein the globules were not numerous; but in proportion as this fluid advanced into the large vessels, the redness, from the increased number and size of the globules, as well as from their approximation to one another, counterbalancing the brilliancy of the yellow substance, presented to the eye a mixed shade of both colours, until at last, upon reaching the trunks, it assumed its original colour from the globules destroying, by their more intimate union, the reflection from the yellow part of the egg.

This reasoning is, besides, supported by facts: for the vessels which crept upon the yellow parts of the breast and belly of the salamander were of different colours: the largest, of a pale red; the middle-sized, orange; and the small ones, yellow (Exp. LXXIII.) That mixture of colours,

lours, however, could only proceed from a more or less vivid light, reflected from the yolk of the egg through the coats of the vessels; since it is now known that these animals have no vessels but what are filled with red globules.

Upon opening the vessels in which the blood, at the time, appeared of a yellow, or brown colour, the fluid which flowed out, formed, near the orifice, a mass of a dark red hue (Exp. CLV.)

When I placed, with great caution, upon a thin plate of glass, any arterial or venous vessels, without disordering the circulation, or carrying along with them any part of the yolk, the blood uniformly presented a red colour, paler, however, in the small vessels (Exp. XXXVII. Dissert. III.)

Before the fortieth hour of incubation, a yellow point was sometimes visible, which, examined by the microscope, without any portion of the yolk, appeared to be a small red body, scattered over with the rude lineaments of sanguineous vessels*.

* The relation of this experiment is here given, not having been made at the same time with the others on the chick.

These united facts appear to establish, that red is the original colour of the blood, although it was for some time extremely pale, and only acquired a florid purple, or scarlet colour, after the complete evolution of the organic system.

The same phænomena occurred in cold-blooded animals. They did not even exhibit the least appearance of that mixture of colours which was observed in the chick, because their vessels were defended from the reflection of the yellow body, as well as from every other coloured fluid. The blood which had not, in tadpoles, for three days after exclusion (Exp. CXLV. CXLVI.) any determinate colour, assumed on the fourth, a reddish tint in the auricle, ventricle, and trunks, in which the greatest quantity of globules were accumulated (Exp. CXLVII. CXLVIII.) The number and approximation of the globules were so essentially necessary to the redness of the blood, that it was even transparent until the sixteenth, or eighteenth day in the small vessels (Exp. CLIV. CLV.); on the twentieth, the whole mass of blood had acquired a red colour (Exp. CLVI.) which became every day more and more florid. It is worthy of remark, that the blood in the chick appeared more or less red before the second day of incubation, whilst that

of

of the tadpole did not acquire the same colour, until the fortieth day after exclusion. In the first, the arterial and venous fluid exhibited on the fifth, a purple colour (Exp. CXXVII); whilst in the second, it continued of a pale red until the fiftieth (Exp. CLXII.) and only acquired, on the sixtieth, or rather the seventy-first day, the brilliancy it possesses in full grown animals (Exp. CLXIV. CLXV.) The low temperature of the blood in tadpoles, relatively to that of the chick, seemed to me partly to occasion this difference. The facts which appeared in the course of my examination, in order to ascertain whether the yellow colour of the blood proceeded from a great deficiency of that fluid, or from a long want of food, have compelled me to reject the opinion of Haller on this subject. I perceived in fact, this yellow, and even the mixture of yellow and red, of which he speaks; but I flatter myself, with being able to prove, that this mixture of colours, as in the chick, was only the effect of an optical illusion. For upon examining, with refracted light (which was employed by Haller), the mesentery of several frogs, which had sustained a long privation of food, I observed an obscure white in the small arterial and venous branches, a yellow tint in the middle-sized, a dark yellow in the large vessels, and a more or less florid red in the trunks of this membrane. But upon the substitution of reflected light, of all these different colours, the red only remained, and was evident throughout the vessels, although much paler in the capillary ramifications, and less brilliant than in animals which had not suffered from want of food (Exp. XXXI. XXXII.) The blood in salamanders being more tenacious of its colour, it was necessary to withhold their food a much longer time, in order to produce the same effects, which were observable on examining with refracted and reflected light the vessels of the frog (Exp. XXXII.)

When almost a complete depletion of blood had been produced in the mesenteric vessels of the frog, the globules appeared reddish by reflected, and of a pale shining yellow by refracted light (Exp. LXXVIII. LXXXVIII. Dissert. III). Such was even the contrast of these shades, that they were evident to the naked eye in the large vessels.

The opposite results produced by these two methods of examination, are, in my opinion, susceptible of a satisfactory explanation. For, as the globules are singly permeable by the luminous

minous rays, it follows, that those in the capillary branches are so surrounded by the refracted light, that the red, peculiar to each of them, being eclipsed by its lustre, can only present a pale whitish cloud. In the large vessels, on the contrary, the globules, either from their greater number, or more near approximation, affording less easy access to the light, were observed to incline towards a more or less bright yellow; whilst the very great number of globules in the trunks, and large cavities, being nearly inaccessible to the light, continued to preserve their red colour. Hence, it must be evident, that refracted light produces upon the mesenteric veins and arteries, the same effects as the yolk of the egg on the vessels of the chick. But, the blood examined by light, reflected only from the surface of the globules, exhibited its true and natural colour throughout the vascular system; and, if it appeared paler in animals that had been some time deprived of food, this effect proceeded rather from the smaller quantity of the blood, than a diminution of its colour.

From these facts we must conclude, that red is the original colour of the blood; that in proportion to the growth of the animal, and the strength and evolution of the vascular system, this colour becomes more vivid, and afterwards acquires that purple shade by which it is distinguished in a state of health. That the want of nourishment, by diminishing the vital energy, and consequently that of the heart, and sanguiferous system, enfeebles the different degrees of this colour, until it is almost entirely effaced. In short, that those white, shining, and yellow tints, &c. are the effect of an optical illusion, or some other cause.

I ought here to correct an error which had slipt into my treatise upon animal re-productions (Chap. XXXIV), in which it is said, that the globules, in tadpoles, were of a pale yellow colour. At that time, I employed refracted light, by which the blood of these animals appeared of a true yellow; but, it was changed into a dark florid purple, by the use of that kind of refracted light, which I have described in the introduction to this work, and which I employed in my experiments upon tadpoles.

It farther results from the details in which we have been engaged, that several celebrated anatomists have been erroneously led to admit the existence of serous, lymphatic vessels, wherein circulate

circulate yellow, or colourless globules. The truth is, that these appearances proceed from the employment of refracted light, and that these supposed lymphatics* make a part of the sanguiferous

* No part of the animal economy has more occupied the attention of physiologists, for nearly half a century, than the system of vessels denominated, from their structure, valvular lymphatics. These vessels, it was formerly supposed, derived their origin from the capillary arteries, with which they were frequently confounded; while, at the same time, the office of absorption was altogether attributed to the sanguiferous veins. The anatomists of this island, in particular, have, however, long ago demonstrated, that the valvular lymphatics are not continuations of the lymphatic arteries; but constitute a distinct genus of vessels, which, with the lacteals, are comprehended under the name of the absorbent system: the knowledge, and study of which have thrown considerable light upon many pathological phænomena, and greatly contributed to advance medical science. The lymphatics, it is true, have, in some parts of the human system, eluded our most industrious researches; but, unless we deny the existence of every thing which does not fall under the cognizance of our senses, and reject all reasoning from analogy, it must seem sufficiently probable, that they are generally diffused throughout every part of the animal frame. As the motion of the fluids, in these vessels, is carried on without any *vis a tergo*, or any mechanism analogous to the functions of the heart; and

guiferous system; since the same globules appear when viewed by refracted light, yellowish, or of a shining white, in the small branches, and of a reddish colour in the large vessels (Exp. LXVIII. LXIX. LXX.); upon the adoption,

and as, in the lymphatics of some animals, the valvular structure is wholly wanting, except at their terminations, it seems reasonable to infer, that their coats are of an active, and contractile nature. If, then, we apply this to the circulation of the blood, and reason from analogy, we shall be led to conclude, that the sanguiferous system is, in like manner, endowed with a contractile power, and that this susceptibility, (whether dependent on an inherent or influent energy) is essential to the circulation, secretions, and other important functions of the living system. Although, our Author's knowledge of this part of the animal economy seems to have been very incorrect, we may yet safely affirm, that few men were in general, better qualified to explore the depths of science, or to unfold the arcana of nature: his experiments appear uniformly to have been conducted with great caution, and to be related with equal impartially: his deductions are evidently the result of sound argument, and solid judgment, except in a very few instances, wherein, it cannot be dissembled, he has been betrayed by prejudice, or a blind attachment for a pre-conceived theory, to the adoption of opinions which, to those who enter into the investigation of the subject, must appear not only controvertible, but, in direct opposition to the evidence of his own experiments. *R. H.*

however,

however, of reflected light, those different gradations of colours change into a red, and florid purple: Experiments XXVIII. LXVIII. and more particularly LXX. appear to me entirely to resolve this question (5). I pretend not wholly to deny the existence of the lymphatics, for although they are concealed from the sight, I believe that, independently of the sanguiferous system, the animal machine is provided with minute canals, which contain only a serous, or mucous fluid: all I contend for is, that those which have been arranged in the class of lymphatics, belong to a different order of vessels. Farther, that an invisible fluid circulates in the venous, and arterial vessels (6), which serve as a vehicle to the red globules, is a fact, which may be ascertained, either from the motion, which they exhibit in the capillary veins, and even upon the surface of the mesentery itself, without coming into actual contact with each other (Exp. LVI. LVIII. LIX. LXVIII. LXXI. LXXIII. CXXX.) and without experiencing the least impression, from the vascular membranes (Exp. LVIII. LXXIII.); or by their passing spontaneously from a state of inaction, independent of any reciprocal collision (Exp. LXXII.), and these effects which are evident at an early period after the exclusion of the tad-

 pole,

pole, &c. (Exp. LXXIII. CXLIX. CL. CLII.) indubitably prove, that this fluid has then an existence, since it is necessary, not only to maintain, but to communicate the first impulsion to the circulation.——I shall conclude this result with a single observation. In speaking of tadpoles, I have said, that the union of several globules was necessary, during some days, in order to distinguish their red colour. I did not mean to assert, that the colour of the blood proceeded from the accumulation of globules, or that singly they had not a reddish tint; for, I believe that each globule possesses an inherent colour, but so pale and feeble, as not to be evident, unless they are in a considerable quantity. In fact, when viewed one by one, the globules, in the chick and tadpole, excepting during the first days, were all of a red colour (Exp. LVI. LXIV. CXXIV. CLIV. CLVI.) which sometimes even resisted the impression of refracted light (Exp. XLIX.): their number, however, and near approximation, appeared to heighten the redness of the blood (Exp. XXVIII. LVI. LXVIII. LXIX.)

TWENTY-THIRD RESULT.

We have hitherto given the appellation of globules to the red particles of the blood; and, in in thus conforming to the language of physiologists, we have not departed from truth; as these molecules were nearly of a spherical figure (Exp. XXVIII. LXV. LXVI. CXV. CXLIX.) and possessed the same form and size in young, as in full grown animals.

TWENTY-FOURTH RESULT.

An elastic property has been, by turns, accorded and refused to the globules. Whilst many have contended, that they experience either from friction, or by passing through the sinuosities of the vessels, a change of figure and volume, others have affirmed, that they are unsusceptible of any sensible modification.

I have endeavoured to throw some light upon this contested, and obscure point. The arteries, in which the pulsations were evident, appeared to me well calculated to answer this purpose; because the globules, producing by their action against the sides of these vessels, the phænomena of pulsation, must experience, unquestionably, a re-action, from the vascular coats, which is communicated to the molecules in the axis of the canal: and the globules cannot yield to the influence of two opposing forces, if their organization be susceptible of change, without an alteration in their form and volume. Such, however, was the rapid motion of the globules, that it was impossible to ascertain, whether they were elastic, until the circulation was abated, by the artificial compression of the heart, or impaired action of the vascular system, when the motion of each globule was readily distinguishable; although, even then, it was not evident, that the reciprocal collision of the globules, or their friction against the coats of the vessels, produced the smallest change in their size or figure.

Those arteries wholly destitute of pulsation, as well as the capillary vessels, wherein the globules circulated singly, gave not a more satisfactory result (Exp. LVIII. CXXX.). Disgusted, by so many useless researches, I renounced a pursuit, which I should wholly have forgotten, had not the blood in the gills of the young salamander revived my curiosity, or rather afforded a solution to my enquiries. I had the satisfaction of discovering that, in this animal, the globules were elastic, and I am so well convinced of this fact, as to rest upon it the truth of this important, and delicate question (Exp. LXXIII.).

Although,

Although, Haller had twice observed a change occur in the figure, and size of the globules, he nevertheless doubted the truth of their elasticity. Upon this subject, it is observed, by this celebrated physiologist,

" In numerosissimis animalculis minoribus glo-
" bulos solitarios per minimas venulas, ferri vidi,
" perque frequentes earum venarumanfractus iter
" sibi aperire. Vidi quantum ad excitandam eam
" opinionem satis est, sed id utique non vidi quod
" sufficiat ad convincendum hominem unice veri
" studiosum, micatio enim aliqua adfuit, alterius-
" que subinde fasciculæ, lucidæ modo, et modo
" obscuræ in globulo alternæ apparitio." *Physiol. tom.* 11, *pag.* 59.

I cannot but applaud the philosophic caution of Haller, being convinced that the fact which he has related is not fully adequate to the solution of the question. It is even my opinion, that his observation was well founded; because the change in the globules, or rather the optical illusion produced by the refracted light, he employed, disappeared with the reflected light used in the experiment, of which I have spoken, and which entirely removed every suspicion of deception. The globules experienced such an

 evident

evident and considerable elongation, as almost equalled the half of their size; they besides assumed a shape corresponding to the angles and sinuosities of the vessels, and recovered, upon again emerging, their original form. It is, however, incumbent on me to mention, that it does not frequently happen that this change in the figure of the molecules can be discerned so clearly: for, excepting in this instance, which was partly accidental, I have never been able to discover an elastic property in the globules, although I have, several times, repeated the experiment.

TWENTY-FIFTH RESULT.

We agree with Lewenhoeck, that warm-blooded animals, *caeteris paribus*, have a greater number of red globules than those with cold blood. This opinion is certainly just, when we regard these two classes of animals, at the commencement of existence; but upon instituting the same comparison, at a more advanced period, it will be found, that this disproportion has disappeared. Thus, tadpoles, and young salamanders have, in proportion to their size, a less number of red globules than the chick in ovo. It was not uncommon to observe, in the first portions

portions of the capillary ramifications wholly destitute of globules (Exp. LXXIII. CXLIX. CL. CLII.); in the second, however, excepting once, they were always full of red molecules. The same proportion was evident, between the middle-sized, and large vessels, in these two classes of animals; but, as the tadpole and salamander increased in growth, the quantity of blood likewise augmented, so that, after the complete evolution of the vascular system, their vessels were equally full of this fluid, as those of the chick. The same observations are applicable to land, and water frogs, as well as to grey, and green lizards. These animals, however, must be in a state of health, and vigour, otherwise, they have a less number of globules. Haller has made the same observations, respecting frogs.

TWENTY-SIXTH RESULT.

The result of all my experiments have evinced the globules to be of the same size, and figure; excepting that, in the salamander, some were of a spheroidal form, whilst others were round, and only half the size of the former (Exp. LXVI. LXVII. LXX.)

EXPERIMENT

TWENTY-SEVENTH RESULT.

A difference, characteristic of cold, and warm-blooded animals, proceeds from the transparency of the vessels in the latter, enabling us to discern the circulatiôn of the blood, at every period of their existence: whilst, in proportion to the evolution of the former, it is gradually obscured, from the increasing thickness of the vascular coats. Towards the fifth day of incubation, the circulation became less apparent, in the umbilical trunks of the chick (Exp. CXXVII. CXXVIII.); and on the sixth, could only be discerned in the middle-sized branches (Exp. CXXX.) The course of the blood, on the nineteenth day, was perceived with difficulty, even in the smaller ramifications, from the more compact texture of the vessels (Exp. CXLIII.)

The motion of the fluids could scarcely be seen after the fourteenth day, in those vessels, which were distributed to the membrane of the yolk (Exp. CXL.): and, even in the body of the chick itself, at the same period, the circulation ceased to be evident, as much from the greater depth, to which the arterial and venous vessels had penetrated, into the cellular substance, and the greater opacity of their coats, as from the feathers

feathers with which the animal was already covered.

TWENTY-EIGHTH RESULT.

We shall conclude these results, with a single remark, respecting the organization of the chick. At first, two principal veins and arteries were evident (Exp. CXV.); and afterwards, two small veins, which increased so as to cover the two large arteries (Exp. CXVII. CXVIII. CXIX.) or to pursue the same direction (Exp. CXLIV.) At last, we discovered a prodigious number of arterial, and venous branches, of which, no vestige had appeared, during the early period of incubation (Exp. CXVII. CXXVII. CXXVIII.)

Must we hence conclude, that these new vessels were formed during the incubation of the egg? A follower of the theory of Epigenesis, according to which, it is supposed, that the organization of living beings is gradual and successive, would, doubtless, adopt the affirmative side of the question; but, ought we to conclude, that a thing has no existence, merely because it does not fall under the cognizance of our senses? The organization of the viscera in the chick, to confine myself to our subject, is absolutely invisible, at an early period of incubation: yet, we are

are compelled to admit their pre-existence, since digestion, nutrition, and other principal functions are already performed, by the animal in embryo. The lungs, and liver of the chick, were only visible, when they had attained a size equal to the thousandth part of an inch; and the other viscera were gradually evolved from the seventieth to the hundred and fortieth hour. Ought we then to believe, that all these parts were formed in succession, more particularly if it be true, as Haller has demonstrated, that the chick exists before fecundation? Now, if these different viscera were not produced successively, we must presume that nature would follow the same course, respecting the formation of the new vessels of the chick, and that they are co-existent with the arteries and veins discerned at first, but that their evolution is longer delayed, from the smallness of their capacity, not allowing the blood to penetrate with the same facility.

DISSERTATION III.

ON THE PHÆNOMENA OF LANGUID CIRCULATION; AND THE MOTION OF THE BLOOD, INDEPENDENT OF THE ACTION OF THE HEART, AND THE PULSATION OF THE ARTERIES.

SYNTHETICAL VIEW OF THE EXPERIMENTS.

SECTION I.

On the phænomena of languid circulation *.

EXPERIMENT I.

On one frog.

THE blood circulated in the mesenteric vessels of this frog, which was of the largest size, with equal force, and rapidity. After thirty-six hours, the venous fluid exhibited its usual momentum,

* What is here understood by languid circulation, is that, which proceeds from the progressive diminution of the vital functions.

and the arterial an unequal motion, that is, less rapid, during the diastole of the heart.

The blood, on the second day, scarcely flowed in the veins; it stagnated at every diastole, in the arteries, and only recovered some degree of motion, upon the contraction of the heart. At the beginning of the third day, the circulation was no longer perceivable; and the vessels, excepting some small branches, remained full of blood.

I ought here to mention that I placed, under a glass vase, without altogether interrupting the communication with the atmosphere, the different animals which I examined; by this method, the circulation was protracted, as the vessels, &c. remained longer moist, than when left exposed to the external air.

EXPERIMENT II.

Although the blood, in the mesenteric vessels, circulated with rapidity, its colour had, in a great measure, disappeared.

The velocity of the venous fluid gradually diminished, so as scarcely to evince any appearance of motion. At the end of eight, or nine hours, the arterial blood moved more languidly in the diastole, than the systole of the heart. During these two periods, its momentum abated, by degrees, and at last ceased, in an imperceptible manner, through all the ramifications.

EXPERIMENT III.

On four frogs.

I shall here only relate the results: the circulation ceased sometimes sooner, sometimes later; but the retardation of the blood was the same as in the foregoing experiment: and all the vessels (those of a single frog excepted) remained full of this fluid.

EXPERIMENT IV.

On two salamanders.

At the end of eighteen hours, the impulsion of the heart scarcely extended to the arteries. Although the blood stagnated at the beginning of the third day, in the small vessels, it still preserved some motion in the middle-sized, and large ones. When the circulation ceased, the greatest part of the vessels remained full of blood.

EXPERIMENT V.

On two grey lizards.

In the lizards, the circulation was sooner arrested, than in salamanders and frogs. The blood having flowed into the large vessels, the small branches were left almost wholly empty: its motion ceased in the same manner, as in the former experiments.

EXPERIMENT VI.

On several salamanders, frogs, and grey lizards.

Here the mesentery was not fully displayed: for it was my intention, neither to displace this membrane, nor tear asunder the teguments, until the enfeebled action of the vascular system appeared to produce some effect on the circulation. Before, therefore, preparing the animal, I left it extended upon the gibbet for two or three days, after which, the circulation terminated in the same gradual, and insensible manner, as in the experiments already related: and the arterial and venous vessels, likewise, for the most part, remained full of blood.

EXPERIMENT VII.

On several tadpoles; the seventh day after exclusion.

I placed, upon a watch glass, several tadpoles, whose vitality was exhausted by degrees. The changes to which the circulation became subjected, constituted the principal object of my enquiry. The course of the blood was perceivable, only, in the gills, and was like to that, which I have, elsewhere (Exp. CXLIX. CLI. Dissert. I.) compared to a wheel, which revolved, and stopped alternately. This motion (the tadpoles were out of the water) continued during a quarter of an hour, after which, the revolutions became less frequent; and, at last, were only partially performed, until the circulation wholly ceased in the gills, the vessels of which remained full of blood.

EXPERIMENT VIII.

The twelfth day.

The circulation began to be disturbed, after the tadpole had remained out of the water nineteen minutes. The venous blood had lost part of its velocity, in the head, and tail, and the arterial discontinued its course, during the dilatation of the heart. This stagnation continued longer, and the circulation abated, more and more, at every systole, in the venous and arterial vessels, until the circulation insensibly terminated. It is worthy of remark, that it ceased first, in those portions most distant from the heart. The vessels remained full of blood.

EXPERIMENT IX.

The eighteenth day.

This experiment differed from the preceding, only in this, that the tadpole having become more vigorous, the abatement, and cessation of the circulation were delayed to a much later

Wishing to learn, if the motion of the blood ceased sooner in the vessels, in proportion to their distance from the heart, or in consequence of their becoming sooner parched, (which was the case with those of the extremities) I endeavoured to preserve, in both, an equal degree of humidity. But the circulation ceased in the arterial and venous vessels of the tail, sooner than in those of the head: hence, I concluded, that the stagnation of the blood, in these vessels, was occasioned, by their greater distance from the heart.

EXPERIMENT X.

Results of several experiments on full grown tadpoles.

In witnessing the progressive debility of these animals, I observed the same phænomena I have already described, viz. that the circulation terminated, in a gradual, and insensible manner; that it ceased sooner in the arteries, and veins most distant from the heart; and that the vessels, for the most part, remained full of blood.

EXPERIMENT XI.

I next turned my attention to warm-blooded animals, and selected, for the subject of my examination, a turkey egg, after two days incubation. When it had been prepared six minutes, the heart beat more slowly; the arterial fluid stagnated during the diastole, and the venous exhibited an uniform, but extremely languid course. Ten minutes later, the pulsations of the heart were less frequent, and at every diastole the blood even ceased to circulate in the veins. The small remaining motion, which this fluid preserved, during the systole, disappeared by degrees, in the small and large arterial and venous vessels; and upon the stagnation becoming general, the blood was accumulated in the portions nearest the heart.

EXPERIMENT XII.

The results were the same, from the examination of a turkey egg, after four days incubation as in the last experiment; only that before the circulation entirely ceased, the blood exhibited an oscillatory motion, first in the small arteries, afterwards in the middle-sized, and last of all in the large trunks.

EXPERIMENT XIII.

Having already related the effects produced by the slow and progressive debility of the animal, I shall now enquire, what might be those which will result from a violent death. The experiment was easy, and merited attention. After preparing the mesentery of two frogs, and immersing the animals, a few minutes, in a vessel filled with sulphureous gas, the circulation was instantly arrested. The blood with which the vessels were filled, after death, was of a clay colour.

EXPERIMENT

EXPERIMENT XIV.

The foregoing experiment, not having fulfilled the end I had in view, I varied it, so that a stream of the sulphureous gas was directed upon the head of the animal, during the time I examined the mesentery. The blood oscillated, augmented in quickness, took a retrograde direction, and altogether ceased, from the convulsive spasms, no doubt, with which the animal was affected. But scarcely was the vapour withdrawn, until they ceased, and the circulation re-appeared, but, with diminished velocity. After the lingering death of the animal, the vessels, as before, were full of blood.

EXPERIMENT XV.

I exposed two frogs, at different intervals, to the sulphureous vapour somewhat modified: yet, it produced the same effects as formerly: only the velocity of the blood, upon recovering its course, appeared to diminish, in proportion, as the animals were oftener exposed to the sulphureous steams.

EXPERIMENT XVI.

I placed several frogs, under the exhausted receiver of an air pump, in such a manner as

to

to enable me to direct the microscope upon the mesentery; knowing that these animals could exist, a long time, without air. The arterial and venous blood circulated, for two hours, with its usual velocity, after which, it exhibited an unequal motion, or rather a mere abatement, which, three hours later, terminated in absolute rest. I then withdrew the frogs, which had not the least appearance of life.

EXPERIMENT XVII.

On several grey lizards, frogs, and salamanders.

I placed these animals, separately under the exhausted receiver of the air pump: and the results were the same as in the preceding experiment, only the circulation ceased sometimes sooner, sometimes later.

EXPERIMENT XVIII.

On two frogs.

Although the want of air had not produced any change in the circulation, it appeared to me, that I ought not to confine myself to these experiments; for when I examined the animals, the blood, moving with such rapidity, might experience a retardation, which the eye could

not

not perceive; as it is impossible to distinguish the progressive degrees of velocity, which a body loses, whose motions are extremely rapid. I did not therefore exhaust the receiver, until the circulation began to abate; but the blood invariably preserved the remaining degree of motion, with which it was agitated.

SECTION II.

On the effects of the gravity of the blood.

EXPERIMENT XIX.

Having examined the effects of the weight of the blood, in the venous and arterial vessels, I wished to ascertain those, which it would manifest, out of the body. I received in a small vessel, filled with pump water, a few drops of blood drawn from the aorta, or *vena cava* of a living salamander. This fluid formed several flakes, of which the filaments extended to the bottom of the vessel, where they deposited a reddish pellicle, which, examined by the microscope, was discovered to be a mass of sanguineous globules.

EXPERIMENT XX.

The venous and arterial blood, which had coagulated before touching the surface of the water, was precipitated to the bottom of the vessel, with greater rapidity than in the last experiment.

EXPERIMENT XXI.

We killed several salamanders, in different ways, without inducing a consequent coagulation of the blood, in the large or middle-sized vessels. This was usually accomplished by a discharge of electricity, or by covering the animal with common salt. After having employed the first of these methods, I suspended the salamander by the head, in a direction perpendicular to the horizon. The blood, in the vena cava and aorta, was instantly precipitated to the inferior extremities; but recovered its original situation, upon placing the animal in a horizontal position. This fluid flowed rapidly towards the head, upon reversing the salamander, and redescended into the vessels of the tail, when I changed the position of this extremity. The middle-sized vessels exhibited the same phænomena, experiencing only more slowly the effects of gravity, but the circulation, in the small branches, seemed to be little influenced by this law.

EXPERIMENT XXII.

I removed all the viscera contained in the thoracic cavity, without injuring the two trunks of the descending aorta (Exp. II. Dissert. I.) wherein remained some drops of blood. This fluid flowed rapidly from the trunks to the aorta, when the head of the animal was placed in a perpendicular position; but upon reversing it, the blood again passed from the aorta into the trunks with the same velocity.

EXPERIMENT XXIII.

The mesentery was stretched with hooks, for an hour and a half, and the circulation, in several veins, was carried on with extreme languor. I changed the position of the mesentery, and placed it, with the intestines, in such a manner, that the venous blood was obliged to ascend perpendicularly. But far from following this direction, it instantly stopped. I next placed this membrane, in a situation equally favourable to the action of gravity, and the natural course of the blood, which then evinced some degree of quickness, and recovered its usual velocity with the original position of the mesentery.

EXPERIMENT

EXPERIMENT XXIV.

I placed horizontally the mesentery of a frog held stretched with hooks; the circulation, in one artery, diminished, during each diastole of the heart. This vessel had been placed in a situation favourable to the power of gravity, and the circulation was not much increased. I observed the blood, raised at every systole, but again fall back at the end of each contraction. The blood assumed an oscillatory motion, by means of which, the globules arose or descended with the systole or diastole of the heart.

EXPERIMENT XXV.

The blood circulated with rapidity in the mesenteric arteries. The power of gravity produced no change in its motion, whatever might be the position of the vessels, whether perpendicular, horizontal, &c.

EXPERIMENT XXVI.

One artery after having crossed the mesentery, formed upon the stomach, an infinite number of flexures and convolutions, in which the blood moved so rapidly, that it was impossible to discover, if its action was conformable or in opposition to gravity.—

One

One of the arterial mesenteric vessels received four or five globules at a time, the motion of which became more rapid, when influenced by the power of gravity, and almost stopped, when this force was opposed to their course.

EXPERIMENT XXVII.

Several venous ramifications united on emerging from the stomach, into a single trunk, wherein the blood circulated languidly, when these vessels were placed in a horizontal position; but upon experiencing the power of gravity, this fluid redoubled its velocity, and stopped, when obliged to circulate against its own weight.

EXPERIMENT XXVIII.

Upon leaving the animal in a horizontal position, the blood scarcely moved in the peritoneal vein (Exp. LXXXVII. Dessert. 1.): it was precipitated with equal rapidity into the vessels of the tail, or head, according to the position of these extremities. In the first case, the motion of the vein imitated that of an artery; in the second, this vessel recovered its natural action.

EXPERIMENT XXIX.

The blood circulated languidly in the descending vena cava, and the ramifications, which anastomosed

tomosed with it. Upon placing the head of the salamander in a position perpendicular to the horizon, this fluid took a retrograde direction towards the origin of the tail, with a partial reflux into the ramifications of the vena cava: it was precipitated, on the contrary, into the internal parts of the head upon reversing the posture of the animal.

EXPERIMENT XXX.

No change was produced on the momentum of the blood, whatever might be the position of the pulmonic veins.

EXPERIMENT XXXI.

The circulation of the blood, in the descending cave, was unusually rapid. Upon being forced to flow upwards, it continued its course towards the head, but with only half the rapidity it evinced, when this vessel was placed in an opposite position.

EXPERIMENT XXXII.

In a capillary vessel of the ovaries, the blood exhibited an oscillatory motion, which appeared wholly uninfluenced by the action of gravity.

This

This fluid ceased to circulate in the two inferior thirds of the pulmonary artery; but, it flowed throughout this vessel, when seconded by its own weight, and instantly stopped, upon the artery being placed in a direction opposed to its natural course.

EXPERIMENT XXXIII.

If the descending cava formed upon the side of the tail an acute angle with the horizon, the blood proceeded towards the heart with the same velocity, as when this vessel was in a horizontal position. But, in proportion as the angle augmented, the circulation diminished in velocity, and entirely ceased, when it was about eighty degrees.

EXPERIMENT XXXIV.

I placed, in a vertical position, the capillary branches distributed to the different muscles of the neck (Exp. LII. Dissert. I.) but did not perceive, that the momentum of the blood experienced either increase or retardation.

EXPERIMENT XXXV.

Upon placing the descending cava, and several capillary veins, in a situation opposed to the gravity of the blood, this fluid ceased suddenly to circulate in the first vessel, and was precipitated to the side of the tail; whilst, in the other veins, the circulation experienced no retardation.

These vessels, having been so disposed, that the influence of gravity might facilitate the natural motion of the blood, it then proceeded from the *vena cava* into the heart, without experiencing any diminution of velocity in the small veins.

EXPERIMENT XXXVI.

In a small mesenteric artery, the motion of the globules was uniform, but a little augmented during each systole; when forced, however, to take a direction contrary to their weight and natural impulsion, they stagnated during every diastole of the heart.

EXPERIMENT XXXVII.

On five eggs forty-three hours after incubation.

It was more difficult to determine the effects produced by the gravity of the blood in the chick than the salamander: for, after having attached to the gibbet this last animal, we could

turn

turn it in every direction, without deranging the natural position of the vessels. But upon raising up the umbilical vessel of the chick, the membrane of the yolk, falling by its own weight, ruptured wholly, or in part, the ramifications which it drew after it. It was, however, possible to prevent this accident by cautiously detaching this membrane, and placing it upon a thin plate of glass. The vessels which were thus displaced, without disordering the circulation, could, by means of the glass plate, be placed in the various situations in which we wished to examine them; and, in this manner I conducted the following experiments:

The blood in the umbilical arteries circulated by rapid and frequent jets, in the eggs, forty-three hours after incubation (Exp. XV. Dissert. I.): it ascended against its own weight, if the declivity was gradual, but when too abrupt, what it advanced in the systole, it again lost during the following diastole.

Before removing the vessels and placing them upon the glass plate, I observed in the blood, a mixture of brown, yellow, and red colours (Exp. CXV. Dissert. I.): but after their displacement, this fluid became more or less red in proportion to the capacity of these vessels, provided no portion of the yolk was attached to the glass; for then we perceived the three shades of colour already mentioned.

EXPERIMENT XXXVIII.

On three eggs, two days after incubation.

Such was the position of the two umbilical arteries, that the power of gravity could not be contrary to the one, without being favourable to the other. Whilst the blood scarcely moved in the first of these vessels, it had in the second a rapid and uniform course.

EXPERIMENT XXXIX.

On one egg, after two days and three hours incubation.

The two umbilical veins experienced, as before, effects favourable and contrary to gravity; but as the blood in these vessels had an opposite direction to the arterial fluid, its velocity was redoubled in the vein proceeding downwards, and proportionably diminished in the ascending vessel: the vertical position of this last vein even suspended the circulation.

 EXPERIMENT

EXPERIMENT XL.

On two eggs, after two days and eighteen hours incubation.

The small veins, which crept upon the trunks of the two umbilical arteries, were already distinguishable (Exp. CXVII. Dissert. I.): these could not experience an action contrary to gravity, without this power aiding the motion of the blood in the others; thus the arterial fluid diminished in velocity, whilst the venous preserved its usual course.

EXPERIMENT XLI.

On two eggs, at the same period of incubation.

I exposed to the direct or opposing action of gravity the small arteries, which assumed, on being reflected towards the heart, the character of veins (Exp. CXVI. Dissert. I.) These, which possessed a capacity equal to the transmission of several globules, experienced more or less the effects of its power; whilst those, which only received a single series of these molecules, appeared to be almost wholly exempted from its influence.

SECTION III.

Of the effects which appeared on the opening of some blood vessels.

EXPERIMENT XLII.

Upon opening a mesenteric artery, the blood circulated in all the vessels of this membrane. It instantly formed two opposite currents, the one between the extremity of the vessel and the opening, the other between the opening and the heart: the first had a retrograde motion, the second continued its course with more celerity. After a mutual collision they flowed out at the place which opposed the least resistance, viz. the opening of the artery.

EXPERIMENT XLIII.

The circulation had ceased in the peritoneal vein, yet upon opening this vessel, two opposite currents spouted through the aperture. If the vein was in a horizontal position, the motion of the two currents appeared equally rapid; but if it formed an angle with the horizon, the ascending had a slower course than the descending column.

EXPERIMENT XLIV.

The descending cava, examined in the same manner as the peritoneal vein, afforded a similar result.

EXPERIMENT XLV.

I made a small incision into the pulmonary vein, in which the blood circulated with rapidity. The two opposite currents flowed through the aperture, and the blood in the neighbouring branches proceeded more rapidly towards this vein. After a quarter of an hour, the retrograde column moved slower than the natural current: it afterwards exhibited an oscillatory motion, which was propagated much more towards the extremities of the lungs than the side from whence it originated: and at last, mingling with the usual current, both (the blood having coagulated so as to shut the opening) continued their course towards the auricle; after this manner was the circulation in the pulmonary vein re-established. The opening of the vein in the other lobe having produced the two opposite currents, the retrograde column impelled by the ordinary current, took a direction, for eight minutes, towards the heart. The blood afterwards resumed its natural course, although a few drops flowed through the incision.

EXPERIMENT XLVI.

I made an opening into a large branch of the descending cava; but although the blood had ceased to circulate, it instantly formed two currents, which flowed through the aperture: that from the side of the cava furnished the greatest quantity of red globules.

Another opening in a second branch, wherein the blood had likewise ceased to circulate, afforded the same result.

EXPERIMENT XLVII.

Upon making an incision into the venous mesenteric trunk, the blood, which had stagnated in the splenic vein, directed its course, with the most accelerated momentum, towards the opening through which it flowed, *guttatim,* during three quarters of an hour.

EXPERIMENT XLVIII.

The circulation was carried on languidly in the mesenteric veins and their branches: but no sooner had the trunk of these vessels been opened, than the blood was precipitated through the incision, without excepting even that in the ramifications which were distributed to the intestines. In all these vessels, after eleven minutes, the blood preserved some remains of motion.

EXPERIMENT XLIX.

I made an incision into the trunk of the pulmonary vein, wherein the blood circulated languidly, and oscillated in the attendant artery. The oscillation suddenly ceased, and the momentum which the blood acquired, was communicated with greater force to the artery and its branches, in proportion, as they were near the opening.

In the other pulmonary vein, the blood flowed more rapidly, and circulated by small jets in the corresponding artery. The opening of the first vessel did not appear to increase the momentum of the second. A considerable quantity of blood, furnished by the two opposite currents, flowed through the incisions in the pulmonary veins.

EXPERIMENT L.

The venous mesenteric trunk was scarcely opened, until the blood redoubled its velocity, not only in the branches proceeding directly from this trunk, but even in the splenic vein and the branches, the junction of which formed, at their exit from the stomach, a single canal that passed into the last mentioned vein (Exp. CVI. Dissert. I.)

Upon

Upon making an incision into the pulmonary artery, the blood, which circulated in the nearest branches, assumed a retrograde motion, and flowed through the opening. This fluid preserved between the heart and the incision its usual momentum.

EXPERIMENT LI.

Having interrupted the circulation by means of a ligature upon the aorta, I opened the peritoneal vein. Besides the two opposite currents, the blood flowed, during thirteen minutes, from the small branches towards this vein. Upon another opening being made in the pulmonary vein, the circulation in it was not only re-animated, but an oscillatory motion excited in the attendant artery.

EXPERIMENT LII.

Having interrupted the course of the blood, by placing a ligature upon the aorta, I opened the venous mesenteric trunk; upon which the circulation in the veins proceeding from it was somewhat re-animated. The opening furnished very little blood, owing to the increased momentum of the retrograde current; but scarcely was the equilibrium restored, when the circulation

tion augmented in velocity, not only in the mesenteric veins, but likewise in the smallest ramifications: almost all these vessels remained empty.

EXPERIMENT LIII.

The blood had an oscillatory motion in the descending cava, and in one of its branches; wherein I made an opening, through which the blood, from the cava itself, issued in a considerable quantity; and upon its abatement, that contained in the branch was likewise discharged.

EXPERIMENT LIV.

Having arrested the circulation as usual, by means of a ligature, and opened the pulmonary vein, two opposite currents were instantly perceived spouting through the aperture; and the blood in the large and small veins was discharged into the venous trunk, whilst the satellite artery and its ramifications experienced some agitation.

EXPERIMENT LV.

After having suspended the circulation, I opened the trunk of the splenic vein; the blood remained without motion in that portion included between the incision and the spleen. This vessel anastomosed with the venous mesenteric trunk

trunk (Exp. CXVI. Dissert. I.) the blood in which, flowed through the opening with such force as to suspend the motion of the column furnished by the splenic vein, and even forced it to take a retrograde direction towards this vessel. Upon the abatement, however, of the circulation, the blood in these last veins, having partly recovered its velocity, began to stream through the opening.

EXPERIMENT LVI.

After the suspension of the circulation, I made in a middle-sized vein of the liver a small incision, from which the blood contained in the ramifications of this vessel, continued to issue until it was interrupted by a coagulated mass formed near the orifice: upon, however, the removal of this obstacle, the blood began again to spout through the same opening.

EXPERIMENT LVII.

I opened a small branch of the descending cava, in which the blood had an oscillatory motion. The exit of this fluid through the opening was intercepted, at the end of thirteen minutes by a collection of globules, which being removed, it again flowed in jets through the same aperture.

EXPERIMENT

EXPERIMENT LVIII.

Having prepared the salamander without interrupting the circulation, the motion of the blood in the arterial and venous trunk of the mesentery, was extremely languid. I then opened the last vessel, in order to observe whether the acceleration would be communicated to the fluid contained in the artery; but the blood only redoubled its velocity in the arteria ramifications, which formed a junction with the mesenteric veins.

EXPERIMENT LIX.

I opened three small mesenteric veins, and the blood which had flowed with rapidity, ceased to circulate on each side of the opening.

The incision of two other mesenteric veins a little larger, produced the opposite currents already noticed.

EXPERIMENT LX.

I had scarcely opened different small artéries of the ovary, until the motion of the blood suddenly ceased. This loss of motion, both now and in the last experiment, evidently arose from the readiness with which the orifice closed, in consequence of the thinness of the coats of these vessels;

vessels; as, when kept open with small forceps, the opposite currents were immediately perceived, and the blood flowed, *guttatim*, through the opening.

EXPERIMENT LXI.

The body of the salamander having been placed in a position perpendicular to the horizon, and the circulation suspended, I opened the descending cava, upon which the blood in that portion of the vessel superior to the incision, was immediately precipitated towards the opening through which it escaped: whilst that contained in the inferior portion only began to ascend and stream out some minutes afterwards.

EXPERIMENT LXII.

On four salamanders.

This afforded a similar result to that of the former experiment. The peritoneal vein having been examined in the same manner as the vena cava, the blood which stagnated below the opening took likewise a perpendicular direction.

EXPERIMENT LXIII.

On the chick, two days and twelve hours after incubation.

The trunk of one of the umbilical arteries, in which the circulation was carried on very languidly and by jets, had scarcely been opened, until the motion of the blood ceased between the incision and the extremity of the artery, and redoubled its velocity between the heart and the incision through which it issued.

EXPERIMENT LXIV.

At the same period of incubation.

I opened a branch of the umbilical artery, wherein the blood circulated by small jets. The fluid contained between the incision and the extremity of the vessel, after taking a retrograde direction and allowing a few globules to escape, insensibly stopped: that, on the contrary, which moved in that portion of the branch correspondent to the heart, continued its usual course, and flowed through the opening.

EXPERIMENT LXV.

After two days and twenty hours incubation.

The trunk of an umbilical vein having been opened, the circulation ceased between the incision and the heart: but the blood contained in the portion of the vessel above the puncture, redoubled its velocity and flowed through the aperture. This augmentation of momentum was communicated not only to the ramifications of the vein itself, but likewise to the arterial branches from which it originated. At the end of five minutes, the blood stagnated first in those portions nearest the orifice, but afterwards in the arterial ramifications.—

I punctured the vein anew, and the momentum re-appeared, but continued a much shorter time than before.—

A third opening, during a few minutes, feebly re-animated the circulation: after which I made an incision into a small artery from whence issued some blood, whilst in a branch proceeding from it, this fluid preserved its usual momentum.

EXPERIMENT LXVI.

After two days and twenty-one hours incubation.

After having prepared the egg, I divided an umbilical vein without the least drop of blood issuing from its sides: but the accumulation of globules was so great, that the redness and capacity of this vessel were considerably augmented.

I afterwards made an incision into a capillary vein and artery, situated very near the umbilical vein;

vein; there was no effusion of blood, and the venous vessel became larger and of a darker red. But after having enlarged the apertures, the blood began to stream out and the momentum was re-established from the small veins to the arterial branches. The veins lost the augmentation of capacity produced by the super-abundance of globules.

EXPERIMENT LXVII.

At the same period of incubation.

I successively divided four veins and two arteries (Exp. CXVIII. Dissert. I.) From the aperture in the arteries, a few drops of blood were effused; and the two opposite currents were evident in the veins, upon the application of a slight stimulus.

EXPERIMENT LXVIII.

After four days incubation.

Although the circulation of the blood had ceased, upon opening a vein, it instantly formed two currents which flowed through the aperture. The incision of another vein produced only a single current, in that portion of the vessel detached from the heart.

EXPERIMENT LXIX.

At the same period of incubation.

The division of a venous branch so disordered the circulation in a neighbouring vessel, that the blood contained in both flowed towards the incision.—The trunk of this vessel having been secured, the blood during three or four minutes, preserved its usual motion between the ligature and the extremity of the vessel: it afterwards took a retrograde course towards the opening, through which it escaped. The blood from all the ramifications proceeded to the venous trunk, but unable to overcome the obstacle opposed to its course, by the ligature, returned backwards and streamed through the aperture.—

The blood being obliged to ascend before reaching the opening, this vein furnished a very inconsiderable number of globules.

EXPERIMENT LXX.

After five days incubation.

The circulation being suspended between the ligature and the extremity of a large umbilical branch, the accumulation of globules was so considerable, as not only to heighten the colour, but

but likewise to increase the capacity of this branch and its ramifications. A slight incision restored the motion of this fluid, part of which flowed through the opening. Another vein produced a similar result.

EXPERIMENT LXXI.

After six days incubation.

Upon opening a branch of the umbilical vein, the blood stagnated above and below the aperture; but in consequence of making an incision into a much larger vessel, a considerable number of globules were effused from both orifices.

EXPERIMENT LXXII.

After nine days incubation.

The division of some small arterial and venous vessels, which were entwined upon the head, neck, and extremities of the chick (Exp. CXXX. CXXXV. Dissert. I.) produced for the most part one or two currents.

EXPERIMENT LXXIII.

After thirteen days incubation.

Such a considerable quantity of blood issued from an opening which I made, into the large artery of the yolk (Exp. CXXXIII. Dissert. I.) that the vessel became extremely pale. I could then perceive the circulation, which the obscurity of the artery hitherto concealed. The blood flowed in two currents, which after a mutual collision was precipitated through the aperture. They appeared like two reddish columns, the diameter of which insensibly diminished, until they almost ceased to be visible; or like a thread suspended in the axis of a vessel, whose capacity remains the same.

EXPERIMENT LXXIV.

After fourteen days incubation.

The repetition of the foregoing experiment afforded a similar result. The blood, however, escaped by small jets, and moved slower during the diastole than the systole of the heart.

SECTION IV.

On the effects produced by the destruction of the heart and the aorta, upon the motion of the blood.

EXPERIMENT LXXV.

The circulation was suspended in the arterial, although not in the venous system, by the destruction of the heart.

The

The motion of the blood in the pulmonary vein and its ramifications continued during seventeen minutes, although much slower than formerly.

EXPERIMENT LXXVI.

The momentum of the blood redoubled in a small vein of one of the ovaries, a single minute after the destruction of the heart: eleven minutes later the circulation entirely ceased.

EXPERIMENT LXXVII.

On two salamanders.

These animals had been much exhausted before I opened the curvature of the aorta. At first the motion of the blood was increased in the pulmonary veins; but, afterwards insensibly diminished until it entirely ceased.

EXPERIMENT LXXVIII.

The circulation in the mesenteric vein ceased only sixteen minutes, after the destruction of the heart: upon which the blood became extremely pale. Although it had a reddish tint when viewed by reflected light; it appeared of a shining yellow when refracted was employed.

EXPERIMENT LXXIX.

Scarcely had an incision been made into the heart, when the blood in the descending aorta took a retrograde direction; and, although obliged to ascend from the position of the animal, almost entirely escaped through the opening.

EXPERIMENT LXXX.

An opening which I made into the aorta, did not change the natural direction of the blood in the pulmonary vein: the motion of which continued until the whole globules had flowed out.

EXPERIMENT LXXXI.

On two salamanders.

The blood with which the lungs were filled, moved with the greatest rapidity. The opening of the heart diminished the circulation, and twelve minutes afterwards it ceased in the arterial vessels: the venous remained full of blood.

The arterial fluid in the lungs of another salamander, insensibly took a retrograde course, whilst the velocity of the venous redoubled.

EXPERIMENT LXXXII.

I placed the animal in a position, that I could examine at once the descending aorta, the pulmonary artery, and a net-work of vessels which covered the ovaries. The momentum was in all of them considerably increased, but upon opening the heart, the blood in the descending aorta although obliged to ascend, was immediately precipitated through the incision. In the pulmonary artery it took likewise a retrograde direction, although its motion was much slower, and sooner ceased than in the aorta. It circulated with less rapidity in the small vessels of the ovaries, but no reflux occurred.

EXPERIMENT LXXXIII.

The blood circulated by jets in two mesenteric arteries; but, a reflux immediately succeeded to the opening of the heart, although this fluid was forced to ascend perpendicularly.

EXPERIMENT LXXXIV.

The incision of the heart considerably augmented the velocity of the blood in the descending cava. This fluid ascended against its own weight; but the vein forming with the horizon an obtuse angle, the blood after having ceased to circulate, descended by degrees to the inferior part of the vessel, where it accumulated in a very great quantity. Upon, however, making an incision into this vein, at a small distance from the liver, the blood which had been precipitated into the interior of the tail, resumed its course towards the opening through which it wholly flowed.

EXPERIMENT LXXXV.

The preceding experiment induced me to open the heart, before making an incision into the vena cava. The momentum of the blood was redoubled, after which the circulation wholly ceased; but was again restored by a second incision. I then compressed this vessel, upon which part of the blood escaped by the opening: the residue recovered its motion, and had throughout the cava the appearance of a reddish cloud, which was dissipated across the incision. The blood contained in the branches then entered this vessel, wherein it flowed in a feeble stream, until it likewise found a passage through the aperture.

EXPERIMENT LXXXVI.

After having repeated, with equal success, the foregoing experiments, I opened (without injuring the heart) the descending cava near the origin of the tail. The blood continued its usual course above and below the incision: the superior column took a direction from the side of the heart, and the inferior towards the opening through which it flowed. I pressed out that part of the fluid contained in the cava between the liver and the incision, wishing to observe whether the blood took a retrograde course from the heart towards this vein, which was, in fact, filled by the inter-communicating branches situated between the liver and the origin of the tail.

EXPERIMENT LXXXVII.

Being unable to ascertain the object of my enquiry, I opened the vena cava near the liver, at which place it did not receive any branches. The blood which circulated between the heart and the incision, suddenly changed its direction, and continued for three quarters of an hour to spout through the opening. The stream having become slower and less abundant, I forced out the residue of the globules, upon which the vein lost its red colour, but it was soon restored by the reflux of blood from the side of the heart. Whatever might be the position of the vena cava, the result was uniformly the same.

EXPERIMENT

EXPERIMENT LXXXVIII.

The circulation had ceased in all the mesenteric vessels, with the exception of some very small arteries. The heart, however, was scarcely opened, until the arterial and venous fluid took a direction towards the incision, and for seven or eight minutes continued to flow through the opening. The residue of the globules were of a pale white when viewed by refracted light, but of a dark and florid red when reflected was employed.

EXPERIMENT LXXXIX.

Upon dividing the aorta, the blood spouted from the divided portions: that, however, which was attached to the ventricle furnished the greatest quantity.

EXPERIMENT XC.

The destruction of the heart, after a few minutes, diminished and suspended the circulation of the blood in a small vein of the gall-bladder.

EXPERIMENT XCI.

Scarcely had the heart been opened, when the blood flowed from the branches into the descending aorta; and three minutes later its motion

altogether

altogether ceased. I then made an incision into a portion of the vessel nearest the heart, upon which the blood contained in the branches manifested somewhat of a retrograde motion.

EXPERIMENT XCII.

Wishing to ascertain what effects would be produced upon the circulation, by the decollation of the animal, I found that although it considerably diminished the velocity of the blood, the circulation continued during five hours.

EXPERIMENT XCIII.

I divided the body of a salamander, between the heart and the mesentery. The blood pursued its usual course in the mesenteric veins; but took a retrograde direction in the correspondent arteries.

EXPERIMENT XCIV.

On two frogs, and two salamanders.

After decollation the circulation was maintained seven hours, in the mesenteric vessels of one of the frogs and salamanders; the blood only losing its momentum in proportion to the diminution of its quantity.

The division of the body of the other two animals, between the heart and the mesentery, accelerated the circulation in the mesenteric veins, and produced in the arterial vessels a retrograde motion.

EXPERIMENT XCV.

ON THE CHICK.

After two days and twelve hours incubation.

The destruction of the heart communicated a retrograde motion to the blood in the umbilical arteries.

EXPERIMENT XCVI.

At the same period.

Upon destroying the heart immediately after its contraction, the arterial fluid took a retrograde direction, and the momentum of the venous blood was redoubled. The circulation continued, in this manner, during eighteen minutes.

EXPERIMENT XCVII.

After three days incubation.

Although the circulation had ceased, the moment I opened the heart, a few drops of blood issued from the sides of the arterial and venous vessels.

EXPERIMENT XCVIII.

At the same period.

The circulation was extremely rapid; scarcely, however, had the heart been opened when the arterial fluid ceased to circulate, whilst that in the veins increased in velocity, and wholly issued through the opening: notwithstanding which, the veins preserved their usual diameter. These last vessels were disposed in such a manner, that the blood was forced to ascend, but, in this direction its momentum somewhat abated. The arteries remained full of blood, but upon opening one of their trunks, not a single drop of this fluid was effused.

EXPERIMENT XCIX.

At the same period.

The excision of the heart accelerated the circulation in a vein, and produced a retrograde course in an artery.

EXPERIMENT C.

After five days incubation.

The circulation was extremely languid, previous to the excision of the heart: in consequence of which the blood instantly stagnated, except

except in several small veins, wherein this fluid continued to circulate in opposition to its own gravity.

EXPERIMENT CI.

After six days incubation.

The destruction of the heart having suspended the course of the venous blood, I opened two trunks wherein this fluid formed opposite currents, and flowed through the opening.

EXPERIMENT CII.

ON TADPOLES.

The fourteenth day after exclusion.

The destruction of the heart suspended the circulation of the blood in the smallest vessels of the tail; whilst, however, this fluid redoubled its velocity in the large vein, and took a refluent course towards the heart in the attendant artery.

EXPERIMENT CIII.

Eighteenth day.

After the excision of the heart, the circulation was maintained some time in several ramifications of the tail; whilst the motion of the blood in the large vein became augmented, that in in the accompanying artery took a retrograde course towards the heart.

EXPERIMENT CIV.

The result of several experiments was, that the destruction or opening of the heart produced, whatever might be the age of the tadpole, a retrograde motion in the large artery of the tail, and an accelerated velocity of the circulation in the correspondent vein.

SECTION V.

Are the opposite currents of the blood, towards the incision of the vessels, the effect of nervous irritation?

EXPERIMENT CV.

Having punctured with a needle the spinal marrow of a frog, the animal immediately experienced the most violent convulsions, which prevented me distinguishing the circulation in the mesenteric vessels; but, after having gradually ceased, I perceived that the puncture had produced no disorder whatever in the course of the circulation.

EXPERIMENT CVI.

On two salamanders.

The same phænomena resulted from the examination of these two animals. The convulsions produced at first some disorder in the circulation; but they had scarcely ceased when the blood recovered its usual motion.

EXPERIMENT CVII.

On four salamanders, and four frogs.

Instead of puncturing, I divided transversely the spinal marrow: the effects were the same as in the foregoing experiment.

EXPERIMENT CVIII.

On four salamanders, and five frogs.

Notwithstanding the destruction of different portions of the spinal marrow, the results were not different.

EXPERIMENT CIX.

On three salamanders, and three frogs.

I successively divided the different nerves that went out from the spinal marrow: the parts to which they were distributed, experienced during a few minutes a violent commotion, and the blood

blood sometimes augmented in velocity, sometimes assumed a retrograde or oscillatory motion; but, it recovered its usual course when the convulsions had ceased.

EXPERIMENT CX.

On three frogs.

In the midst of the whitish muscles of the thigh, crept a considerable number of arterial and venous vessels, in which the blood circulated with its usual celerity: upon dividing the crural nerve, the most violent convulsions ensued, and were propagated to the extremity of the limb, when I could no longer discern the course of the blood; it soon, however, again became evident, and recovered its usual velocity.

EXPERIMENT CXI.

In frogs the brain is composed of two lobes and two appendices, the one anterior, and the other posterior: the first extends to the muzzle, the second forms the beginning of the spinal marrow. We could denude and even entirely divide this viscus, without occasioning the immediate death of the animal. Different punctures into the brain of a frog produced general convulsions, and the circulation in the mesenteric vessels experienced some irregularities, which, however, disappeared with the cause from which they originated.

EXPERIMENT CXII.

On four frogs.

Two of these frogs, examined in the same manner as those in the foregoing experiments, presented similar phænomena: and even the entire division of the brain in the two other animals, made no alteration in the results.

EXPERIMENT CXIII.

On five salamanders.

The puncturing and removal of the brain occasioned some disorder in the circulation, which, however, ceased with the nervous spasms.

EXPERIMENT CXIV.

These experiments, however, appeared to me insufficient to determine, whether nervous irritation produced the irregularities observable in the circulation. They might depend, perhaps, upon the mechanical agitation of the parts, produced by the disordered action of the nervous system; as a simple concussion frequently deranges the motion of the blood. To solve this

doubt,

doubt, I fixed the head and tail of the frog with pins, in the same manner as I had formerly prepared the integuments (Exp. I. Dissert. I.): the muscles, nevertheless, experienced a tremulous motion, which affected the vascular system: but, in the vessels, which from their position, did not experience this muscular re-action, such as the mesenteric and pulmonary, the blood preserved its usual momentum; although at different times I had punctured and cut the spinal marrow.

EXPERIMENT CXV.

On three salamanders.

The results were conformable to those of the preceding experiment.

EXPERIMENT CXVI.

On three salamanders.

In the pulmonary artery and vein, the blood stagnated in one portion, whilst in another it circulated by jets, notwithstanding an incision having been made into the spinal marrow.

EXPERIMENT CXVII.

On several salamanders.

The most extensive lesion of the brain, even the entire excision of this viscus produced no change

change whatever upon the circulation in the pulmonary and mesenteric vessels.

EXPERIMENT CXVIII.

On two salamanders.

I pushed the point of a probe into the canal of the spine, and destroyed almost the whole medullary substance, without the circulation being disordered in the pulmonary or mesenteric vessels.

EXPERIMENT CXIX.

On several frogs.

I repeated with an uniform effect experiments CXIV. CXVI. CXVIII.

EXPERIMENT CXX.

These experiments induced me to enquire what degree of vital energy might remain after the privation of the heart and brain, and the excision of which of these viscera would produce the greatest effects upon the animal economy. The destruction of the brain occasioned in three salamanders the most violent convulsions; they remained with their eyes closed, and appeared to be altogether deprived of voluntary motion. A stimulus revived their excitability, but it continued only for an instant.—

I divided, at the same time, the heart in other three salamanders of the same size and vigour as the former: the consequence of this treatment was, however, much less violent, these animals continuing to move and perform their usual functions.—It is worthy of remark, that notwithstanding the privation of the heart, and the pain which they had suffered several hours upon the gibbet, they took to flight the moment they were set at liberty, whilst those, on the contrary, which had been deprived of the brain, exhibited, after seven minutes, the most irregular phænomena: they opened with difficulty their eyes and mouth, and seemed scarcely capable of loco-motion, making only a few feeble efforts to escape from the vessel wherein they were confined; which were immediately succeeded by a state of torpor, that increased as I had conjectured on the second day, and about the middle of the third these animals were quite dead: whilst the three salamanders, notwithstanding their greater strength, immediately after the excision of the heart, lived only forty-eight hours.

EXPERIMENT CXXI.

I repeated the foregoing experiment upon eight salamanders, and the results were similar; those which were deprived of the brain living longer than the others in which the heart was destroyed.

EXPERIMENT CXXII.

Four frogs, immediately upon the destruction of the brain, experienced, during seven or eight minutes, the most violent convulsions. The application of a very active stimulus was afterwards found necessary, in order to excite those animals to action: the hæmorrhage had been very considerable.—

I divided the heart of four other frogs; but although they continued to move, and keep their eyes open, they survived the operation but thirty-six hours. One of those, on the contrary, the brain of which had been destroyed, died only on the third, another on the fourth, and the two others on the fifth day.

EXPERIMENT CXXIII.

Having repeated the foregoing experiments upon a great number of frogs and salamanders, I uniformly experienced, that these animals died sooner which had been deprived of the heart than the brain; although after the excision of the first viscus, they evinced greater strength and vigour, than after the destruction of the second.—

second.—The death of these amphibious animals seemed to be much accelerated, by allowing them to remain under water after these different operations: the reason of which doubtless was, that in consequence of exhaustion, they could no longer rise to the surface of this fluid, in order to obtain a sufficiency of vital air, for the purposes of respiration, and the support of the animal functions.

SECTION VI.

Do the currents of the blood towards the incision in the vessels, proceed from the contraction of their coats?

EXPERIMENT CXXIV.

As the superabundance of blood occasioned a considerable distention of the vessels, (Exp. LXVI. LXX.) it seemed, that they should contract, in proportion to the diminution of this fluid. Before, however, submitting this last question to the test of experiment, I thought it still necessary to confirm the former by additional facts. For this purpose, I placed a ligature upon the middle of the descending aorta of a frog: the portion betwixt it and the heart increased in capacity and became of a deeper red; whilst that portion beneath the ligature was pale and

 collapsed,

collapsed, and although it only retained a small quantity of blood, its diameter did not appear to be in the least diminished.

EXPERIMENT CXXV.

Upon securing the *vena cava* near its insertion into the liver, the circulation ceased below the ligature, first in the abdomen, then at the beginning of the tail, and afterwards at the extremity of the vessel, which was inflated and of a dark red colour approaching to black.

EXPERIMENT CXXVI.

It is easy to apply a ligature upon a large vessel, but somewhat difficult to secure, in a similar manner, the middle-sized, and above all the small ones; what, however, intercepts as effectually the course of the blood, is to compress, for some time with forceps, the vessel we wish to examine. I compressed in this way the pulmonary vein towards the middle of that viscus, upon which the accumulation of globules was so great, that the vessel became extremely red; its capacity, however, did not appear to be augmented.

EXPERIMENT CXXVII.

The blood ceased to circulate above and below the compression which I made upon the peritoneal vein, without producing any enlargement of its capacity.

EXPERIMENT CXXVIII.

I compressed a small mesenteric vein, formed by two branches which proceeded from the intestines. The circulation ceased on each side of the compression, except in the ramifications, where it formed two opposite currents, which continued to flow until the circulation ceased; the capacity of the vein, however, was not increased.

EXPERIMENT CXXIX.

The compression of the venous mesenteric trunk suspended the circulation throughout its branches; except in one, wherein the blood flowed in a direction from the heart. The diameter of the trunk appeared to be enlarged, which was not the case with its ramifications.

EXPERIMENT CXXX.

I interrupted several times, in different places, the course of the circulation in the pulmonary artery: the blood stagnated in the portion superior to the ligature; but in the inferior it preserved its usual momentum, penetrating into the ramifications situated beneath the compression.

EXPERIMENT CXXXI.

I compressed alternately four veins and two arteries, which extended from the stomach to the liver. The circulation uniformly ceased above and below the ligature, without in the least affecting the capacity of these vessels.

EXPERIMENT CXXXII.

I suspended the circulation in a vein of the gall-bladder. The blood, which this vessel contained in a very great quantity, ceased to flow not only in the trunk but in its ramifications; yet I could not perceive that they were either increased, or diminished in capacity.

EXPERIMENT CXXXIII.

On several salamanders.

The mesenteric vessels exhibited the following phænomena: when I examined the veins, the blood stagnated above and below the compression; but the accumulation was greatest on the side of the intestines. This was reversed in the arteries, which experienced a small degree of distention, in those portions containing the greatest quantity of blood.

EXPERIMENT CXXXIV.

On several eggs, at a more or less advanced period of incubation.

Similar effects were not produced by compression upon the small vessels of the chick. Sometimes the arteries were distended between the heart and the ligature, and the veins between the ligature and the extremities. The compression being removed, the blood resumed its course, and the vessels their original capacity.

EXPERIMENT CXXXV.

With respect to the question, whether the diameter of the vessels diminished when the blood escaped through the opening made in their sides, and whether they became entirely, or almost, empty, I judged it proper to measure them, before and after the experiment. The capacity of the *vena cava*, which nearly equalled one line, was reduced after the incision of the heart and efflux of the blood, first to one-eighteenth and afterwards to one-seventeenth of a line.

EXPERIMENT CXXXVI.

The diameter of the descending aorta which was, before the experiment, one six-tenths of a line,

line, diminished after its depletion, nearly one-tenth of a line.

EXPERIMENT CXXXVII.

The diameter of the *vena cava*, near the liver, was about nine-tenths; and that of the descending aorta towards the middle of the body one half less. The blood in these two vessels having flowed through an incision in the heart, the capacity of the first was reduced nearly one-tenth of a line, whilst the second remained the same.

EXPERIMENT CXXXVIII.

The effusion of the blood produced no change in the diameter of the two pulmonary veins, which near the lungs was about three-tenths of a line; but that of the descending aorta, which before the experiment was nearly five-tenths, lost one-tenth of a line.

EXPERIMENT CXXXIX.

The diameter of the two pulmonary arteries, which was nearly two-tenths of a line, experienced no diminution after the experiment; and that of the descending cava scarcely lost one-tenth of a line.

EXPERIMENT CXL.

The efflux of the blood produced no alteration in the diameter of the pulmonary arteries and veins of three salamanders.

EXPERIMENT CXLI.

Although a considerable quantity of blood escaped from the peritoneal vein, its diameter remained undiminished.

EXPERIMENT CXLII.

On several salamanders.

The smallness of the mesenteric vessels permitted us only to examine them by the eye, through a microscope. The results of several examinations of the arterial and venous mesenteric trunks, as well as the branches proceeding from them, were, that their diameters always remained the same, whatever had been the quantity of blood effused.

EXPERIMENT CXLIII.

On several eggs, after a longer or shorter period of incubation.

The mesenteric vessels of the chick afforded similar results to those of the salamander.

EXPERIMENT CXLIV.

Although it appeared to be demonstrated, that the effusion of the blood occasioned no contraction whatever in the vessels, it was nevertheless possible, that their internal capacity might experience some diminution. For, in fact, if the cavity of the arteries and veins be invested by a cellular substance, yielding and susceptible of impression; it is evident, that the vessels which had undergone a complete depletion, ought to diminish in capacity according to the former pressure, or rather the lateral friction of the globules. It was easy to ascertain this fact, either by measuring the thickness of the vascular coats, or the internal capacity of the vessels, before and after the extravasation of the blood. Having preferred the last method as more convenient, I measured the section of a pulmonary artery, before making an incision into the heart: in consequence of which, the blood took a retrograde direction towards the opening, through which it almost entirely escaped. Upon comparing the section of this vessel, I found it absolutely the same as before.

EXPERIMENT CXLV.

The vessels of several other salamanders, upon which I repeated the foregoing experiment, afforded a similar result.

SECTION

SECTION VII.

Does the pulsation of the arteries depend upon the dilatation, produced in their sides, by the momentum of the blood, during the systole of the heart? Or is it the effect of a local action occasioned in these vessels, by the displacement of that organ?

EXPERIMENT CXLVI.

We have noticed elsewhere the pulsation of the arteries in salamanders, land and water frogs, grey and green lizards, and the chick *in ovo* (Result IV. Dissert. II.) We then observed, without entering into any detail, that the pulsations are accompanied by a motion of dilatation, which we shall now examine, beginning with the aorta of the salamander. This large trunk, after forming near the heart, as we have already seen, a kind of curvature, proceeds toward the head, where it is lost in a muscular tissue. The aorta pulsates throughout its length, and is dilated at the same time, but in an unequal manner, viz. about one-third in the curvature near its exit from the heart, and nearly one-twentieth in the rest of its extent.——

Although

Although the dilatation of the aorta, or rather the augmentation of its diameter, during each pulsation, was evident to the eye, I was disposed, nevertheless, to support this fact by new proofs. The vessel in question being nearly isolated from the heart even to the head, I passed around it an open ring which was afterwards closed, leaving its internal diameter somewhat larger than that of the aorta in a state of diastole. I attached a silk thread to this ring, by which I held it suspended, in such a manner, as not to come into contact with the arterial trunk. The space included between the ring and the aorta lessened during the pulsation, but became more considerable upon the contraction of this vessel. I then diminished the size of the ring, so that the distention of the aorta throughout its circumference filled, at each diastole, the empty space which remained.

Several other salamanders afforded a similar result.

EXPERIMENT CXLVII.

After the salamander had been prepared a long time, the heart propelled only a small quantity of blood into the canal of the aorta; which, although situated horizontally, exhibited some

degree

degree of dilatation. I then placed the animal in a perpendicular position, with the head upwards, but the action of the heart was become so languid, that the blood could not ascend into the aorta, and the distension was limited to the curvature. The coats of this artery were whitish, and its capacity had diminished. Upon afterwards turning the head of the animal downwards, the blood resumed its course, and the aorta became immediately dilated throughout its extent.

EXPERIMENT CXLVIII.

On several salamanders.

I expelled the blood without injuring the auricle, the ventricle, or the aorta; but, although entirely empty, and considerably contracted, they still exhibited some feeble remains of their usual action. I then divided the trunk of the aorta, yet the curvature, although thus detached, continued to contract and dilate during half an hour.

A similar result was afforded by three other salamanders, with this difference, that the contraction and dilatation did not continue equally long in all of them.

EXPERIMENT CXLIX.

On several salamanders.

I cut out the heart and aorta in several salamanders, without disturbing the position, or relation, which subsisted between them in the breast. In two of these animals, however, the order of the systole and diastole was changed, that is, the heart and aorta contracted and dilated at the same time, during seven minutes. The motion of the aorta afterwards became less frequent than that of the ventricle; and it ceased at last sooner in the former than in the latter.

The result was different in three other salamanders; the aorta contracted when the heart was at rest, and *vice versa*. Sometimes the action of the heart continued longer than that of the aorta; sometimes the motion ceased later in the aorta than in the heart.

EXPERIMENT CL.

The foregoing experiment having been repeated on other five salamanders, the heart in four of them contracted longer than the aorta; but in the fifth, the motion of this vessel continued longer. In these animals, the action of the heart and aorta was seldom synchronous.

EXPERIMENT CLI.

On several salamanders.

Upon raising up the aorta, and dividing that portion which is inserted into the muscular tissue, its action immediately ceased; excepting in the curvature,

curvature, which continued for some minutes to contract and dilate.

EXPERIMENT CLII.

On three salamanders.

After the transverse division of the aorta at its curvature, the motion continued in the two separated portions. The orifice of that which remained attached to the heart, and through which a great quantity of blood escaped, was enlarged at every pulsation; and afterwards became diminished in capacity, and very soon entirely ceased.

EXPERIMENT CLIII.

On several salamanders.

It is a property of the arteries to become elongated during their pulsation: yet this elongation does not occur in the aorta of salamanders; which was observed to shorten upon each systole as it approached the heart. This phænomenon was more evident in proportion to the languid motion of that viscus, either in consequence of less blood being propelled into the canal of the aorta, or from one or other of these organs having been separated from the body of the animal.

EXPERIMENT CLIV.

On two salamanders.

The heart by its contractions could only, however, draw towards it that portion of the aorta with which it remained connected. The descending aorta and the curvatures, which it formed, became evidently elongated and distended during each systole of that organ.

EXPERIMENT CLV.

The descending aorta of a large and vigorous animal, experienced a considerable dilatation and elongation. I compressed this vessel towards the middle of the abdomen; upon which that portion below the ligature became extremely white, and lost the power of performing its usual actions; whilst the superior portion preserved its original colour and motion. Upon making a second compression, the space included between the two ligatures remained full of blood, but ceased to contract; the dilatation and elongation were still, however, maintained in that portion of the vessel betwixt the second ligature and the heart.

EXPERIMENT CLVI.

I have already spoken in the first dissertation (Exp. CXXXIII.) of an artery, the pulsations of which exhibited a species of vermicular motion. I shall now add, that this vessel augmented in diameter and size throughout its extent. The pulsations ceased in that portion of it which was included between two ligatures.

EXPERIMENT

EXPERIMENT CLVII.

On several land and water frogs.

The trunk of the aorta in these animals, is composed of a great bulb which divides into several large vessels. The change produced by the systole of the heart, upon the curvature of the aorta, in the salamander, occurred in this bulb, and the trunks to which it gave rise.

EXPERIMENT CLVIII.

On several grey lizards.

The lungs in the grey lizard are much larger, although shorter than in the salamander: each lobe receiving two large arteries, and an equal number of veins. The pulsations in the trunks of the former were so strong, that their diameters became one half larger; but the branches exhibited a more feeble action, and the distention diminished, in proportion to the smallness of the vessels. The elongation of the arteries was in the ratio of their dilatation; and when viewed obliquely, they described, during inspiration, an arc, the extent of which was increased by the pulsations; but during expiration, these arteries formed several folds and re-duplications, which contracted and elongated, so as, at first sight, to represent the appearance of a worm.

EXPERIMENT CLIX.

On three grey lizards.

The aorta of the grey lizard, unlike that of the salamander and frog, is divided into two trunks closely united, from which proceed different branches. The compression of these trunks instantly suspended the pulsation below the ligature.

EXPERIMENT CLX.

On one green lizard.

The vascular system of these small serpents has the same organization as that of grey lizards. The two arteries of each lobe of the lungs were dilated and contracted from the extremity to the origin of this viscus; the distention being, however more considerable in this last portion, where the diameter of the artery was double that of the other. These motions were more evident some hours after the preparation of the animal, because they were performed with less rapidity. The distention of the pulmonary arteries exceeded that of the curvature of the aorta: and the grey lizards exhibited the same phænomenon.

EXPERIMENT

EXPERIMENT CLXI.

On several frogs, grey and green lizards.

In speaking of the distention of the pulmonary arteries of grey and green lizards, and the curvature of the aorta in land and water frogs, I have had always in view the lateral dilatation, or that which is evident between the right and left side of the vessel. Anxious, however, to observe, whether the oblique and superior portions of these arteries (those underneath being concealed from the view) dilated, I placed thin plates of iron betwixt the interstices that separated them, by which means I found, that they were uniformly distended in every direction.

EXPERIMENT CLXII.

On a grey and green lizards.

The elongation and dilatation of the pulmonary arteries ceased, in those portions which were included between two ligatures.

EXPERIMENT CLXIII.

On two salamanders.

This circumstance did not occur in the curvature of the aorta in the salamander. The systole and diastole continued in that portion included between the ligatures, until the destruction of the heart itself.

EXPERIMENT CLXIV.

On several salamanders.

After having compressed the two extremities of the aortal trunk, and divided it beyond the ligatures, I placed it upon a table, without its discontinuing to contract and dilate. These motions, however, were limited to the curvature in the aorta which was empty; but in the other which contained some drops of blood, it was propagated throughout the space contained between the ligatures. I then allowed the blood to escape from this last vessel, upon which the curvature alone preserved the power of contraction and dilatation.

EXPERIMENT CLXV.

In the salamander, and the land and water frog, the aortal trunk, and more particularly its curvature, is composed of a fleshy and muscular tunic.

EXPERIMENT CLXVI.

On three salamanders, and three land frogs.

The descending *vena cava* of the salamanders experienced, from the liver to the auricle, a considerable

siderable dilatation and contraction; which likewise occurred in the two trunks of the ascending *cava* of the land frogs. After an incision had been made into these vessels, and the blood allowed to flow out, they continued to preserve some degree of systole and diastole.

EXPERIMENT CLXVII.

On a green lizard.

I divided the descending aorta below the liver, upon which the inferior portion ceased to beat, whilst the superior continued its pulsations. The quantity of blood, which escaped from this vessel, was so considerable, that it would have been left entirely empty, had not the incision been closed by the contraction of its sides. The blood thus confined began to oscillate, advancing during the systole, and taking a retrograde course upon each diastole of the heart. In the first case the artery was dilated; in the second, its diameter was diminised.—

After having viewed some time this curious phænomenon, I divided another portion of the artery: the pulsation was only maintained on the side of the heart. Upon pressing out the remaining blood in this vessel, the pulsatory motion

tion suddenly ceased; but, it re-commenced, although very feebly, when this fluid again began to penetrate into the artery.—

I placed the artery in such a situation, that the blood was obliged to ascend against its gravity: but, it was instantly precipitated into the ventricle, and only afterwards resumed its ordinary course during the systole, stagnating upon each diastole of the heart. The pulsations of the artery extended no farther than the blood; but upon bending the vessel, so that its ascent was less rapid, this fluid circulated through a more considerable space, and the pulsatory motion was propagated to a greater distance; they were, in short, evident throughout the artery, because the column of blood struck the whole surface of its sides. The portion of the aorta which received the impression of the globules was only susceptible of contraction and dilatation; but the mass of blood being insensibly dissipated, the pulsations were discontinued some time, before the motion of the heart ceased.

EXPERIMENT CLXVIII.

After the division of the descending aorta of a green lizard, the inferior portion ceased to pulsate, whilst the superior continued to contract

during

during eight minutes: this last portion contained a small quantity of blood, which exhibited no sensible motion: the diastole and systole of the heart were, however, maintained a long time.

EXPERIMENT CLXIX.

I made a double compression upon the descending aorta of a green lizard, the pulsations only continued in that portion situated between the heart and the first ligature; and the blood in it took a retrograde course or advanced according to the diastole or systole of the heart. Scarcely were the two ligatures removed, when the circulation and pulsatory motion re-commenced throughout the extent of the aorta.—

A thin plate of iron applied against the sides of the aorta, so as to intercept the course of the blood, produced the same effects as a ligature.

EXPERIMENT CLXX.

Experiments CLXVII. and CLXIX. were repeated with equal success upon the descending aorta of a green lizard.

EXPERIMENT CLXXI.

Upon making an incision into the trunk of the *vena cava* of a green lizard, the blood took a retrograde course in the descending aorta, and its contractions were immediately discontinued. A considerable number of globules escaped through the aperture, and the residue having coagulated in the orifice, the circulation with some degree of pulsation was re-established.

DISSERTATION

DISSERTATION IV.

ON THE PHÆNOMENA OF LANGUID CIRCULATION; ON THE MOTION OF THE BLOOD, INDEPENDENT OF THE ACTION OF THE HEART; AND ON THE PULSATION OF THE ARTERIES.

ANALYTICAL VIEW.

Of the results from the experiments in the third dissertation

FIRST RESULT.

HALLER, so far as I know, is the only physiologist who has given an exact and elaborate detail of the phænomena of languid circulation. To a languor, at first, more or less evident, succeeds sometimes a rapid, and at others a slow motion. This irregularity is followed by the blood taking a retrograde course, which terminates in an oscillatory motion, the column of blood appearing to vibrate like a pendulum, from the centre to the periphery, and from the periphery to the centre. This motion continues during several hours, and the natural course of the blood is often re-established; but the strength of the animal

animal becoming exhausted by degrees, the oscillation is then followed by a complete stagnation of this fluid; which occurs successively in the small, middle-sized, and large vessels. The mass of blood diminishes in proportion to the loss of its velocity, and the vessels remain almost empty.

These irregularities in the arterial, are likewise evident in the venous fluid. They succeed each other alternately, and sometimes even the flux and reflux occur at the same time; so that whilst the blood takes a retrograde course in one vein, it preserves its natural motion in another, and the circulation is often restored by the collision of these opposing currents.

Such are the principal phænomena observed, by Haller, in languid circulation: his experiments, however, were made upon the mesentery, and after it had been displaced, and prepared with hooks, and we have already observed, in the introduction, to how much error and fallacy, this method is liable, amongst which I have been compelled to reckon the greatest part of the irregularities I have mentioned (7.)

With

With the exception of a small degree of oscillation in the arteries, (Exp. XII. Dissert. III. and XXIV. CI. Dissert. I.) the other phænomena observed a constant and regular order: the arterial blood, which at first had an uniform course, lost more or less quickly its equilibrium, and abated in velocity at each diastole of the heart: to this abatement soon succeeded a complete stagnation, except during the systole, when the blood preserved some remains of motion, which, however, disappeared by degrees. Thus the circulation ceased in the arteries, by a successive and gradual diminution of momentum, without any flux or reflux, intermittent or vibratory motion.

The motion of the blood in the veins, ceased in the same gradual manner; and these different phænomena were alike evident in the arterial and venous fluid of cold and warm-blooded animals (Exp. XI.) not only immediately after exclusion, but at a more advanced period of their lives (Exp. VII. VIII. IX. X.) either when the mesentery was slightly displayed (Exp. I. II. III. IV. V.) or allowed to remain in its natural position (Exp. VI.) either when the animal was placed under the exhausted receiver of an air pump (Exp. XVI. XVII. XVIII.) and perished

rished by degrees (Exp. I. II. III. IV. V. VI. VII. VIII. IX. X. XI.) or by a violent death (Exp. XIV. XV.) The circulation ceased always first in those vessels most distant from the heart (Exp. VIII. IX. X. CXXVI. Dissert. I.) Sometimes, after the death of the animal, the vessels preserved only a small quantity of blood (Exp. III. V. VI. XI.) but usually they remained more or less full of this fluid (Exp. I. III. IV. VI. VII. VIII. X. XIII. XIV. and CXV. CXVIII. CIX. CXXVI. Dissert. I.)

SECOND RESULT.

The blood of all animals is endowed with the principle of gravity; it is heavier than lymph or water, and whatever be the position of the organs in a dead body, it accumulates by its own weight in the most dependent parts. The same phænomena was observed, by Haller, in moribund frogs. From the vertical position of the mesentery, the blood fell to the bottom of the veins, which, by their transparency, resembled whitish filaments; when placed in an opposite situation, the globules returned into these vessels, and appeared of their usual redness. This physiologist observing a column of blood perpendicular to the table, upon which he had extended the frog, had scarcely reversed the position of

this

this table, when the current changed its direction, and descended instead of ascending.

These experiments, which were attempted by Haller alone, upon living animals, open a vast field worthy the curiosity of the naturalist, and in which I have endeavoured to examine—1. The effects of gravity upon the blood stagnating in the vessels, as well as after it has escaped; 2. The alteration which the contrary, or favourable action of this power, produces upon feeble, or very languid circulation. 3. In a word, whether the large, middle-sized, and small vessels are alike subjected to its laws. The weight of the blood in a living salamander considerably exceeded fountain water: this fluid, whether venous or arterial, poured drop by drop upon its surface, was precipitated to the bottom with greater rapidity than when previously coagulated (Exp. XIX. XX.)

The weight of the blood must, doubtless, be owing to the red globules (Exp. XIX.) of which, iron forms one of the principal elements.

The effects of gravity in animals deprived of life, were in an inverse ratio of the smallness of the vessels, that is, more considerable in the large, less evident in the middle-sized, and almost imperceptible in the small capillaries (Exp. XXI. XXII. XXVI. XXVII. XXXII. XXXIV. XXXV. XXXVI. XL. XLI.) When the action of gravity was exercised in conformity with the natural course of the blood, it augmented the velocity of this fluid in the midle-sized vessels (Exp. XXIII. XXIV. XXVI. XXVIII. XXIX. XXXI. XXXV. XXXVIII. XXXIX.) but, if its force was exerted in an opposite direction, the circulation abated, became retrograde, or altogether ceased in proportion to its power (Exp. XXIII. XXIV. XXVI. XXVIII. XXIX. XXXI. XXXII. XXXIII. XXXV. XXXVIII. XXXIX. XL.)

It was only when the blood flowed in the middle-sized vessels with very great rapidity, that the circulation continued independent of the power of gravity (Exp. XXV. XXVI. XXX.)

THIRD RESULT.

This result confirms a most important point in medicine. No sooner was a vein opened, than the blood which it contained, that of the neighbouring branches, and of the inter-communicating arteries, redoubled in velocity, and escaped through the opening. This fact, discovered by Bellini,

Bellini, after having experienced the greatest opposition, has obtained from the experiments of Heide and Haller, general belief. My researches upon this important question, have produced the following results: 1. After the partial or entire division of a vein filled with blood, sometimes two opposite currents were evident, which streamed through the incision (Exp. XLV. XLIX. LIX. LXXI. LXXII.) sometimes only one column (Exp. LXV. LXXII.) and at others a complete stagnation above and below the division (Exp. LIX. LXVI. LXVII. LXXI. LXXII.)

2. The two opposite currents took place, although, before the incision, the venous fluid had ceased to circulate (Exp. XLIII. XLIV. XLVI. LI. LXI. LXII. LXVIII. LXX. CI.)—

3. In both cases, whether the blood circulated, or had previously ceased, that in the vein which was opened, as well as in the ramifications belonging to it, flowed towards the aperture, through which it escaped (Exp. XLV. XLVII. XLVIII. L. LI. LII. LIV. LV. LVI. LXV.)—

4. The blood in the artery, inter-communicating with the vein that was opened, recovered

or accelerated its course, according to the stagnation or velocity which it possessed before the operation (Exp. XLIX. LI. LIV. LVIII. LXV. LXVI.)

5. The puncturing of the arteries produced similar phænomena; the blood forming two opposite currents, which flowed through the incision (Exp. XLII. L. LXIV. LXXII. LXXIII. LXXIV.) or stagnating in the portions above and below the opening (Exp. LXXII.)—

6. The venous and arterial fluid ceased to circulate and flow through the opening, in consequence of the diminished energy of the vascular system, allowing the sides of the vessel to close so as to shut up the orifice: for, in fact, upon re-opening it, the blood again streamed out, and the circulation was restored throughout the vessel (Exp. LXVI. LXVII.)—

7. It is worthy of remark, that upon making an incision into a vessel of an unequal diameter, the blood flowed from the largest portion (Exp. XLVI.) and sometimes even with such force and activity, as to suspend the current in the strait portion of the artery or vein, which could not circulate, until the quantity and velocity of the

former column had diminished (Exp. LII. LIII. LV.)—

8. It is not less astonishing, that after several incisions, the residue of the blood, which had ceased to circulate, should partly recover its momentum and flow through the second or third opening (Exp. LXV. LXXXIV. LXXXV. XCI.)—

9. The accumulation of a mass of coagulated blood, in the orifice, frequently re-established the circulation (Exp. XLV. LVI.) but scarcely was it removed, when the blood continued to spurt through the incision (Exp. LVI. LVII.) Haller had previously made the same observation.—

FOURTH RESULT.

The excision of the heart and aorta, produced similar effects upon the circulation. For if the venous or arterial blood sometimes ceased to flow (Exp. LXXV. XCVIII. C. CI.) it more frequently happened, that the first took a retrograde course towards the opening, through which it escaped (Exp. LXXIX. LXXXI. LXXXII. LXXXIII. LXXXIX. XCI. XCV. XCVI. XCIX. CXLIV.) and the second proceeding

 from

from the same side either preserved its usual momentum (Exp. LXXV. LXXVIII. LXXXI. C.) or redoubled in velocity (Exp. LXXVI. LXXVII. LXXX. LXXXIV. LXXXV. LXXXVI. XCVIII. XCIX.)—

Although the circulation was generally suspended, an incision into the heart restored it in the venous and arterial vessels, and the blood streamed through the opening (Exp. LXXXVIII. XCVII.)

FIFTH RESULT.

Whence the cause of the current, towards the aperture in the vessels, or the heart, which continued even some time after the removal of that viscus (Exp. LXXV. LXXVI. LXXVII. LXXVIII. LXXXI. LXXXII. LXXXVIII. XCVI.)? The influence of gravity upon the circulation (Result II.) could not concur to produce this phænomenon, since the column of blood flowed against its own weight towards the incision (Exp. XLIII. XLIV. LXI. LXII. LXXXIII. LXXXIV. LXXXV. LXXXVII.)—

Scarcely had we opened either the heart, or a blood vessel, when the animal was seized with the most violent convulsions, occasioned, unquestionably,

questionably, by the division of the nervous filaments, with which these parts were provided. Could the accelerated momentum of the blood, towards the incision, proceed from these convulsions? Although this supposition appeared improbable, I conceived it incumbent on me to observe attentively all the phænomena which occurred in the vascular system, immediately upon the division or irritation of the nerves.—

In consequence of puncturing, or destroying the medullary substance, the animal experienced the most violent convulsions, the effects of which were communicated to the circulation; but, the nervous commotion having ceased, the blood resumed its usual course, even after the destruction of the brain itself (Exp. CV. CVI. CVII. CVIII. CIX. CX. CXI. CXII. CXIII.)—

The more I reflected upon this circumstance, the more I became confirmed in my former conjecture: in fact, although I had several times witnessed the current of the blood flowing towards the opening, notwithstanding the regular and constant action of the nerves, I still hesitated whether the irregularities, which ensued in the motion of the blood upon the irritation of this system, proceeded from that irritation, or from a simple mechanical concussion; and my observations would not permit me to doubt, that these irregularities depended on an agitation of the parts, since by preventing its occurrence, whatever might be the violence of the nervous spasms, they produced no change in the circulation (Exp. CXIV. CXV. CXVI. CXVII. CXVIII. CXIX.)—

I was then obliged to search for some other cause, but before entering into these details, I shall notice the remarkable difference between the degree of strength and vitality possessed by those animals which had been deprived of the heart or brain. The removal of the heart did not appear to produce an immediate effect on the economy of their system. They made use of their members, running, leaping, and precipitating themselves into the water, swimming, and in short, performing the same actions as when in a state of health. But those animals, on the contrary, in which the brain was destroyed, were immediately deprived of sensibility and irritability; and if they appeared, upon recovering from a kind of lethargy, to regain the use of their members, they nevertheless remained in a state of stupor and debility. They, however, lived four or five days, and sometimes even longer,

 whilst

whilst those from which the heart had been removed, notwithstanding their greater vigour, died on the first, or second day (Exp. CXX. CXXI. CXXII. CXXIII.) (8)—

The state of drowziness and stupor in animals deprived of the brain is not astonishing, that organ being the principal seat of sensibility, and if the excision of the heart produces death more suddenly, it is, doubtless, owing to the cessation of the circulation, which, on the contrary, was maintained even some time after the destruction of the brain*.

SIXTH

* While it is generally allowed, that by the medium of the nerves we feel, and are enabled to perform motion, numerous facts tend to prove, not only, that an intimate connection subsists between the nervous and sanguiferous systems; but, that they are mutually dependent on each other.—Thus, the functions of the brain, for example, cannot proceed independently of the action of the heart—for when the circulation is suspended, consciousness and sensation immediately cease, as particularly appears in some species of asphyxia. The converse of the above proposition is equally true; since, if the influence of the nerves leading to the heart be completely intercepted, by division or ligature, the functions of that organ are destroyed. The determination of the blood to the genital organs, and to the face in blushing, &c. in consequence

of

SIXTH RESULT.

Haller, astonished at the force and rapidity with which the blood flowed towards an opening made into the heart, or a blood vessel, instituted a great number of experiments to discover the true cause of this phænomenon. The uniform occurrence of this circumstance seemed to offer a solution of the question: the globules tended constantly towards that place, where they were in the greatest quantity. Thus, the blood contained in a dilated portion of a vessel, attracted that from the neighbouring branches, which only again flowed into another portion, wherein a still greater number of globules were accumulated.

of the excitement of certain passions, affords an additional proof of the influence of the *sensorium commune* on the *sanguiferous system*. From these, as well as from a variety of other facts, we may infer, that both nervous energy, and a free circulation are essential to the perfect life, whether of the whole body, or any particular part; and, that if the destruction of the heart appears to prove more speedily fatal than that of the nervous system, it is only, because it can be accomplished in a more complete and effectual manner. Hence, also we may, perhaps, explain, why those animals which have a small brain, and large spinal marrow, live long after decollation, whilst man, and most quadrupeds, who have that organ remarkably large, survive its loss only for a few seconds.

R. H.

These

These accumulations, in two different places, produced opposite currents, which proceeded towards each of those magnetic masses. When this fluid escaped from a vein, and was diffused upon the mesentery, it was sometimes entirely absorbed by the same vessel, from which it may be concluded, with some degree of probability, that the blood accumulates in those cavities which contain the greatest quantity, and that, consequently, in dead animals, it is attracted from the branches to the trunks, and from the trunks to the heart: so that the venous fluid preserves then its usual course, whilst the arterial takes a retrograde direction.—Such was the opinion of Haller, in his first memoir, on the circulation of the blood; but, in that containing the details of his experiments, he declares, that the word attraction, is only employed to describe a certain species of motion. In short, this great physioligist, in treating this important question, far from using the word attraction, has adopted a perfectly different theory, which I shall here present to the reader in his own words.—

" Etsi adeo vim arteriæ contractilem nimis or-
" natam fuisse persuadeor, ad occultæ tamen
" contractionis speciem, vim non illubens refer-
" rem, quam dixi, derivationis, et quæ et in vi-

" vente animale, et in nuper mortuo, sanguinis " motum sola gubernet. Nempe de incisa arte-" ria et perinde quidem de secta vena, sanguis " maxima velocitate effluit, eo modo, ut de vi-" cinis truncis, ramisque, et secundum circuitus " sanguinei leges, et contra easdem, in vulnus " ruat, ut etiam contra ponderis vim, et direc-" tionem naturalem in rimam se præcipitet. Ita " etiam in stagnante sanguine novo nascitur ve-" locitas, et evulso demum corde, aut revinctis " magnis aortæ ramis, atque recisa adeo ab ar-" teriis cordis potentia, tamen sanguis novam " velocitatem acquirit, quæ neque a corde est, " neque a pondere, neque ab ulla potentia nobis " cognita, nisi occultam, atque subtilissimam " vasorum minimorum contractionem admittas, " quæ sanguinem contentum undique urgeat pari " vi, et quæ motum nullum generet, dum omnia " vasa integra sunt, tunc autem se exserat, et " sanguinem in novum motum restituat, et de-" nique per vulnus exprimat, quando locus aliquis " natus est, a quo eandem pressionem dempseris. " Non ideo velim me videri contraria dicere pri-" orum, quando contractilem vim ab arteriis eo-" rum animalium minoribus abesse scripsi. Phæ-" nomena eo loco narravi, negavi conspicuam in " minimis arteriis contractionem reperiri, et nunc " sincerus aliud phænomenon propono, quod non

" videtur

"videtur absque aliqua contractione intelligi "posse: ea vero contractio a vita non pendet, "neque musculosæ est indolis, quæ a morte su-"persit, et ad nativum potius elaterem tensæ "fibræ cellulosæ spectat; ea enim alio etiam in "exemplo, sed lente, et multis continuis diebus, "arterias calidorum animalium rescitas exinanit, "diametrumque minuit, et lumen delet." (*Phys. tom.* II. *pag.* 215.)

Attraction cannot, in fact, produce the currents of the blood towards the opening of the vessels. 1. Because the blood flows equally from the branches to the trunks, and from the trunks to the branches, that is, into those places containing very unequal and disproportionate quantities of blood (Exp. XLVI. LIII. LV.) 2. This reciprocal attraction of the globules, which I have so often observed, is too feeble and languid, in comparison with the velocity with which the blood flows towards the incision. In short, it frequently happens, that the blood penetrates into parts, wherein not a single drop of this fluid can be perceived, although even obliged to ascend perpendicularly (Exp. LXXXIV. LXXXV. LXXXVI. LXXXVII.—

The

The hypothesis of Haller, founded upon an invisible contraction of the vessels, by means of which the blood presses from every part with equal force, redoubles in velocity and streams through the opening, is ingenious, and even probable: before endeavouring to ascertain if this vascular contraction was apparent to the eye, I conceived it incumbent on me to examine, whether the vessels experienced any distention or dilatation, the existence of which upon the principle of their contraction, would afford the most solid support to the theory of the physiologist of Berne. My experiments on this subject have not afforded similar results: several venous and arterial vessels presented an augmentation of diameter (Exp. LXVI. LXX. CXXIV. CXXV. CXXIX. CXXXIII. CXXXIV.) but in a great number of others, it was not evidently increased, although the interruption of the circulation by means of a ligature or compression, had considerably increased the quantity of this fluid (Exp. CXXVI. CXXVII. CXXVIII. CXXIX. CXXXI. CXXXII. CXXXIII.

These researches not having fulfilled my intentions, I was willing to ascertain, in a direct and positive manner, whether the capacity of the venous and arterial vessels experienced any diminution.

diminution. I had several times observed, that these vessels, upon the removal of the ligature or compression, and consequently the accumulation of globules occasioning their distention, recovered that state of contraction which they formerly possessed; but I was anxious to discover, whether this contraction would become greater, on diminishing the quantity of blood, or facilitating its entire evacuation, by the destruction of the heart, &c. In consequence of these experiments, I found that the *aorta* and *vena cava*, in which the diastole and systole were evident, lost somewhat of their diameter, on the extravasation of the blood (Exp. CXXXV. CXXXVI. CXXXVII. CXXXVIII.) but that all the other vessels preserved the same size and capacity: the truth of which, I ascertained by an accurate measurement, before and after the experiment (Exp. CXXXVIII. CXXXIX. CXL. CXLI.)

The very small vessels, which it was impossible to measure, appeared to the eye neither to augment nor diminish in size or diameter (Exp. XCVIII. CXLII. CXLIII. CXLIV. CXLV.)

These

These facts, although unfavourable to the hypothesis of Haller, are yet far from overturning it; (because according to this writer, the contractions of the vessels are so insensible, as not to be perceived) they only place it in the number of those theories which authors gratuitously assume in order to solve some phænomenon of nature.

The contraction, by which the blood is forced towards the opening, depends not, says Haller, either on vitality, or muscular action, but is the effect of the elasticity of the cellular membranes.

"Ea vero contractio à vita non pendet, neque "musculosæ est indolis, quæ à morte supersit, et "ad nativum potius elaterem tensæ fibræ cellu-"losæ spectat." *(Ibid.)*

Can the vessels which are destitute of this power, produce that flux and re-flux of blood towards the opening? Experiments not only evince that this phænomenon occurs in the chick and tadpole, at a very early period, however soft and yielding may be the cellular substance of the venous and arterial coats (Exp. LXVI. LXVII. XCV. XCVI. XCVII. XCVIII. XCIX. CII.) but also, notwithstanding their pliancy and thinness,

ness, the vessels experience a sensible dilatation, when the blood is accumulated in a considerable quantity (Exp. LXVI. LXX.) which could not take place unless the vascular coats were endowed with some degree of elasticity. It is, however, true, that the arterial and venous vessels, lose only the augmentation of capacity occasioned by the accumulation of the blood, and preserve that which they originally possessed. All these facts, well considered, render the opinion of Haller still doubtful.

The two following circumstances are, perhaps, less favourable to his hypothesis. The first is deduced from Experiment LXIII. and LXIV: an incision was scarcely made into the artery, which was the subject of examination, when the column of blood divided into two opposite currents, and streamed through the opening. These currents, at first, filled the whole capacity of the vessels, but they insensibly diminished, until at last they appeared like a small reddish filament, which was scarcely visible, suspended in the axis of the vessel. A follower of Haller would believe, that in proportion as the columns diminished in volume, the sides of the arteries should contract; they preserved, however, the same capacity and size

 which

which they possesed before the experiment (Exp. LXXIII. LXXIV.)

The second fact, which I omitted to relate with the other experiments, is not less conclusive: I took a portion of the intestine of a calf, or some other young animal; and, after having distended and filled it with water, by means of a syringe, I placed upon it a double ligature: but scarcely had the superior part been slightly opened, when the water spouted out, and continued to flow until the extreme tension of the intestine was removed.

This jet of water may be compared to that of the blood from an opening in a vessel: but, if a compression so considerable, as that of the intestine, could only expel a very small quantity of water, can the insensible contraction of an artery or vein, produce a stream so rapid and abundant as that which escaped from the vessels, although the blood was obliged to ascend against its own weight (Exp. LXXIX. LXXXII. LXXXIV. LXXXV. LXXXVI. LXXXVII.)?

These facts are far from overturning the hypothesis of Haller; it only appears to me, that physiologists ought to suspend their opinion, until new

new experiments shall remove those doubts which press upon this theory, or overturn the basis upon which it is founded.

But if the circumstances which we have enumerated, be gratuitous, insufficient, or false, what theory shall we admit? I incline rather to avow my ignorance, than adopt an hypothesis which accords not altogether with the established laws of nature.

SEVENTH RESULT.

A celebrated professor of Montpellier (Lamure) has maintained, that the supposed pulsation of the arteries is an appearance which should be attributed to the action of the heart, elevating them during its contraction. I shall give a short summary of this singular theory; which other writers had adopted before him; but which he has partly appropriated by the new facts with which he has supported it.

It is commonly believed, that the pulsation of the arteries is occasioned by the stroke which they receive from the propulsion of the blood by the heart. According to physiologists, the strongest lateral pressure exceeds the weakest but about one-eightieth, which must therefore be the ultimate augmentation of diameter of the artery:

so that if the capacity of the aorta, for example, be ten lines, its increase will only be one-eighth of a line. The diameter of the intestinal arteries being about one-tenth of a line, must experience, during each dilatation, an increase of one-eight-hundredth; through which the blood runs in half a second. The minute hand of a watch, moves over the space of one-eightieth of a line in one-second: its motion, however, is not apparent; whilst we readily distinguish the pulsation of an arterial vessel, which is five times slower than the motion of the minute hand of a watch; and the size of each is nearly equal. The eye, which cannot perceive the motion of the minute hand, should not then be able to distinguish that of the arteries; unless it proceeded from the friction of the sanguineous globules. When we compress an artery in two places at a little distance from each other, the pulsations are maintained with the same force and rapidity between the ligatures, as in the portions above and below them. All the arteries pulsate at once; and their diastole corresponds with the systole of the heart: the pulsation is not evident underneath the vessel.

The veins are not susceptible of pulsation, because the soft and pliant contexture of their coats render them incapable of receiving the impulse

which

which the action of the heart has a tendency to communicate.

Such are the principal facts and reasoning, from which professor Lamure concluded, that the pulsations of the arteries do not depend on the lateral impulsion of the blood; but that on the contrary, they proceed from the elevation of these vessels produced by the change of position which the heart experiences during its systole.

However ingenious this theory may appear, I hope to convince the reader, that it is founded upon false reasoning and data, contrary to observation and experience.

1. The fresh water and earth worm, in which a large artery performs the functions of the heart, exhibit in a very sensible manner the phænomenon of pulsation: the pulsations are even apparent, as well as the circulation in the vessels of the head and tail, after they are separated from the principal artery. (Riproduzioni Animali, p. 19 et 20.)

2. If the pulsation of the arteries consisted merely in their elevation, no augmentation should take place in the lateral capacity of these vessels:

experiments, however, demonstrate that this is not the case, since the descending aorta of the salamander, and of grey and green lizards augmented considerably in that direction (Exp. CLIV. CLX.) The same circumstance occurred in the bulb of the aorta in land and water frogs (Exp. CLVII.) whilst the lateral capacity of the pulmonary arteries in grey and green lizards, increased nearly one half (Exp. CLVIII. CLX.)

3. On examining with attention the arteries which crept upon the external surface of the membranes, I observed, that the superior and oblique, as well as the lateral portions of their coats, were dilated in an equal and uniform manner (Exp. CLXI.) hence the pulsations cannot be a simple motion from below upwards.

4. The curvature of the aorta in salamanders, which from its isolated situation can be readily examined, was so evidently distended throughout its circumference (Exp. CXLVI.) that the inspection of this large vessel, would of itself be sufficient to overturn the theory of the Professor of Montpellier.

5. After dividing transversely the curvature of the aorta, and attentively observing that portion

tion attached to the heart, I perceived its orifice become much larger during each pulsation (Exp. CLII.) The capacity and size of this vessel are then increased, and far from changing its position, and being elevated, it experiences an actual dilatation.

It is an unquestionable fact, that this dilatation proceeds from the impulsion which is communicated by the heart to the arterial fluid. For when the blood penetrated slowly into the artery, the pulsations were observed in succession, and affected only that portion of the vessel subjected to its stimulus. (Exp. CLXVII. CLXX.) When it took a retrograde direction, or altogether ceased, the pulsations were no longer evident, although the action of the heart continued. (CLXVIII. CLXXI.) When the circulation was interrupted by a ligature, the superior portion which received the impulsion of the heart, continued to beat; whilst in the inferior, which became empty, or in which the blood stagnated, no appearance of dilatation was exhibited. (Exp. CLV. CLXIX. CLXX.) Upon removing the ligature, the circulation and the pulsations were re-established throughout the artery (Exp. CLXIX. CLXX.) they were feeble when the vessel contained only a small quantity of blood (Exp. CXLVII. CLXVII. CLXXI.) but when this fluid was more abundant, they were performed with additional strength and rapidity (Exp. CXLVII.)

Although after depletion, the arterial system lost the power of contraction and dilatation, we must except the curvature of the aorta in land and water frogs, and in the salamander (Exp. CXLVII. CXLVIII. CLVII.) wherein it continued, even after the excision of these organs, and their separation from the body of the animal (Exp. CXLVIII. CLI.) hence we must conclude, that the pulsations in them depend not on the heart's action, but that it is inherent in the aorta itself: an experiment which, from the confession of Lamure himself, is sufficient to overturn his hypothesis. The motions of the aorta, even when not detached from the heart, have no dependance on the action of that viscus. 1. The contractions of the heart and aorta were synchronous, whilst, according to the principle of Lamure, this vessel should dilate when the heart is in a state of systole (Exp. CXLIX. CL.) 2. The motions of the aorta were frequently performed when the heart was at rest; and *vice versa.* (Exp. CXLIX.) 3. The pulsations of this vessel sometimes continued after

the

the destruction of that organ. (Exp. CXLIX. CL.) From all which we may conclude, that the systole and diastole of the aorta do not depend on the action of the heart.

It may perhaps be objected, that if the pulsations of the arteries do not depend upon the change of position in the heart, it is yet doubtful, whether they always proceed from the impulsion of the blood: thus the aorta of frogs and salamanders preserved that action, even after its entire depletion (Exp. CXLVII. CXLVIII. CLVII.) The heart besides ceased not to pulsate, even when it was separated from the body of the animal, although it did not contain a single red globule. Haller replied to this objection, that all bodies which possess a stimulant property, can excite the irritability of the heart, in the same manner as the blood. The air, for instance, is found to be a very active stimulant, by means of a single air bubble contained in the cavities of the heart, detached from the body of of a frog, its motions were continued several hours, and were even renewed after a complete interruption. If then the vascular system preserves its activity, although entirely deprived of blood, we must conceive that its place is supplied by some æriform fluid; since, we learn,

from

from positive experiments, that the heart ceases to beat in the exhausted receiver of an air pump, and recovers its original action on being withdrawn, and again exposed to the atmosphere. Hence these researches prove the existence of an elastic and invisible fluid, contained in the arterial and venous vessels. Besides the pulsations are in a direct ratio of the impulsion of the blood; they begin and cease with the motion of this fluid; and we ought not to be astonished, that the curvature of the aorta, and the vena cava in salamanders, and land frogs, even when detached from the auricle*, and entirely empty of blood, are independent of this law, since the muscular coats of these vessels render them, like the heart, susceptible of the action of the air, or other stimuli (CLXV. CLVI.)

The aorta of salamanders, and land and water frogs, approached during its pulsation the sides of the heart, when in a state of contraction: (Exp. CLIII.) whence it follows, that this vessel

* The fact mentioned in the text is well known to anatomists; and with other circumstances, serve to evince the error of those physiologists, who ascribe the motions of the vena cava, wholly to the regurgitation of the blood in that vessel, by the alternate contractions of the right auricle of the heart. *R. H.*

could

could not suffer that elongation, of which the descending aorta in the salamander, and the pulmonary arteries in the grey lizard are susceptible (Exp. CLIV. CLV. CLVIII.) If this elongation has not given rise to the mistake of the French physician, it is at least favourable to his opinion; because it may be affirmed, that during the elongation of these vessels, they actually change their position, at least in the places where they form curvatures, the diameters of which became then much more considerable. (Exp. CLIV. CLVIII.) It even sometimes happened, that the capacity augmented or diminished, so that the artery represented the stretching and contraction of a worm. (Exp. CLVIII.) But upon examining the arteries with the most minute attention, and with a mind free from any pre-conceived hypothesis, I found that this vermicular motion was always accompanied with an actual increase of capacity. In fact, that the pulsations consisted in an elongation of the artery, which appeared to change its position, as well as in a distension which augmented its capacity. (Exp. CLIV. CLV. CLVIII.)

Lamure endeavours to refute the common opinion of physiologists, and support his own, from the pulsations which are observed in a portion

portion of an artery included between two ligatures. I shall remark, 1. That this phænomenon is not constant and general: I never perceived it in the arteries of the chick, the descending aorta of the green lizard or salamander, nor in the pulmonary vessels of grey and green lizards (Exp. CLV. CLVI. CLXII. CLXIX. CLXX.) even a single ligature was sufficient to destroy, in the inferior portion of the vessel, all appearance of pulsation (Exp. CLV. CLIX.)

2. The aorta in salamanders, the only artery that contracted, notwithstanding the application of two ligatures (Exp. CLXIII.) far from favouring the opinion of Lamure, demonstrates its insufficiency, since the pulsation of this vessel consisted in an actual dilatation (Exp. CLXIII.) which was maintained, notwithstanding the separation of the artery from the heart (Exp. CLXIII.) and even after its division beyond the ligatures, and its extraction from the body of the animal (Exp. CLXIV.) When, however, the portion of the aorta between the ligatures did not contain any red globules, the pulsations were limited to its curvature; whilst, on the contrary, when it was filled with this fluid, they extended from one compression to the other: (Exp. CLXIV.) a phænomenon, which receives a satisfactory

satisfactory solution from the impression of the air acting more powerfully on the aortal curvature than any other portion of the vessel, in consequence of the greater muscularity of its membranes.

It appeared, that when the arteries were endowed with a considerable degree of irritability, the application of two ligatures could not prevent some degree of contraction and dilatation; but, on the contrary, when this principle was extremely feeble, the action of the vessels entirely ceased. Thence, without doubt, the inaction with which all the arteries, except the curvature of the aorta, appeared to be affected beneath the ligatures, did not proceed from a total want of irritability, else the sides of the incision could not contract, so as to come into actual contact (Exp. CLXVII. CLXX.) but from this principle being so feeble, that it was unsusceptible of the action of the air or the blood in a state of stagnation, and required a more active stimulus, such as that of the globules agitated by the impulse of the heart.

It only remains for me to deduce two corollaries from these facts. The first relates to the dilatation of the arteries during their pulsation. This

This dilatation is unequal in different vessels, and in different animals.

1. The distension of the pulmonary arteries in grey and green lizards, was *cæteris paribus*, infinitely more considerable than that of the aorta (Exp. CLX.) which was likewise the case with the curvature of the aorta in salamanders, relatively to the descending aorta. 2. The aorta of grey and green lizards was dilated in a much less degree than that of frogs and salamanders*.

The second corollary proves the inaccuracy of Lamure's calculation respecting the dilatation of the arteries, since the capacity of these vessels, during their pulsation, sometimes increased nearly one half (Exp. CXLVI. CLIV. CLVII. CLVIII. CLX.)

* The reader may rest assured, that I have several times witnessed these two facts, although they were not related with the experiments.

NOTES.

NOTES.

NOTE 1, page 247. Irritability is exercised under the double mode of contraction and dilatation: both together constitute its essence; they act at different intervals without destroying the unity of that principle of which they evince the power.

Irritability is a property of the muscular fibre. The most direct experiments prove, that it is independent of the re-action of the brain and nerves; but it appears subordinate to that particular energy which the nerves possess, but which we must not confound with that power which is only exercised in the *sensorium commune*.

Irritability can only be excited by the application of a stimulus; the action of which is not merely mechanical. It produces an excitement in proportion to the activity of the irritable principle, and *vice versa*; but which varies according to the different parts which are endowed with this power. It appears probable, that the electric fluid is the cause of spontaneous motion, that the blood produces the systole and diastole of the heart; the air, inspiration and expiration; the alimentary juices, the peristaltic motion of the intestines; the urine, the action of the bladder, &c. &c. The duration of any stimulus does not necessarily include its activity. Although the blood, the

the electric fluid, &c. are always present, they do not produce in their different systems a state of perpetual energy or contraction. But is contraction proved to be the active mode of irritability? Should we not rather suppose it to consist in dilatation, if it be a fact, that during the state of relaxation the fibres more nearly approach each other; that they separate, expand and dilate in proportion to their vitality; that pulmonary activity consists in inspiration; that it ceases with life; and that after death, the heart, sphincters, &c. are found to be in a state of contraction?

Note 2, page 254. The mechanism of no system presents itself to the imagination under a more simple and regular aspect than that of the circulation. A hollow muscle, endowed with a considerable force, and supplied with two orders of vessels, which distribute and bring back a red and globular fluid, from the center to the circumference, and from the circumference to the center. Such is at first the idea which we form of the vascular system: but the anatomist, who inclines to scrutinize the organization of these parts, finds the most complicated muscular texture, and in this double order of vessels, a labyrinth of folds and re-duplications, of windings and convolutions, in which he is bewildered and lost. The remarkable difference that this system exhibits in warm and cold-blooded animals, is particularly astonishing. The arterial and venous fluid, in the first, contains less serum, and is of a deeper and more florid colour; its heat is constant and regular in the frozen regions of the North, and in the burning desarts of Africa. This equilibrium is supported by the aid of evaporation, (whatever

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may be the temperature of the surrounding element from 30° to 32° of Reaumur's thermometer. The heat of the blood in the second, on the contrary, is in proportion to that of the atmosphere in which they live. Heat in them appears to be less a constituent principle than a common element, of which they experience the salutary influence. The cold can even coagulate the blood of these animals, without entirely destroying the vitality of their organs. Spallanzani assured me, that he preserved for two years several frogs in a heap of snow: they had become dry, shrivelled, and even friable, and displayed no external appearance of motion or sensibility. In order, however, to recover them from that state of torpor, exposure to a gradual and moderate heat was only necessary. Chance enabled Professor Volta to make the same observation. Some frogs, which he forgot, in a vessel, the water in which had frozen, exhibited, after several months, notwithstanding the disorganization of their parts, and without the aid of artificial heat, strong signs of galvanism.

The heart, in cold-blooded animals, is composed of one ventricle and one auricle. The pulmonary vessels originate from the aorta and *venæ cavæ*: and the blood is propelled at the same instant and by the same force, into all the vascular ramifications. In warm-blooded animals, the heart is quadrilocular. The pulmonary arteries and veins sink directly into the substance of that viscus; they form a distinct order of vessels, which have no kind of communication with those of the other organs. Hence a particular circulation, independent of that carried on in the aorta and *venæ cavæ*, a circulation of which, the action is so favourable to the production and

 extrication

extrication of animal heat, as to render it probable, that from this cause proceeds the difference of temperature in warm and cold-blooded animals. In the last, the influence of the heart's action, is less evident in the venous and arterial vessels: it nevertheless accelerates, retards, disorders, and suspends the circulation; which, however, is still carried on in vessels separated from the heart; and even maintained after the complete excision of that viscus.

The vascular system of warm-blooded animals is intimately connected with that of the nerves: it is, perhaps, impossible to discover any venous or arterial ramification, which is not accompanied with some nervous filament. The heart and brain have the most intimate relation: the slightest lesions in the *medulla oblongata*, or *spinalis*, produce the greatest disorder in the motion of the blood. Whilst in cold-blooded animals, a puncture or incision, made into any of these parts occasion no evident change in the circulation; it even continues to be carried on whole days after the entire destruction of the brain and spinal marrow. Corrupted food, ill assimilated chyle, a long abstinence from food, destroy in the first, the strength and regularity of the vascular action, whilst, the second class of animals can endure a total want of nourishment for several months, without the circulation experiencing the least disorder. The physiologist who reflects on all these differences, will congratulate himself on the researches made by Spallanzani, on an animal, (the chick) the organization of which, has such an intimate relation with that of the human body, as to warrant the application of the most positive and direct induction, on the action and use of the vascular system, and on the diseases with which it is affected.

Note 3, page 260. The application of technical and geometrical processes to sciences which do not admit of it, tends rather to retard than accelerate their progress. It would, doubtless, be a great step towards the advancement of physiology, were it possible to submit to mathematical calculation the laws of the circulation, the affinity of the gastric juices, the mechanism of the secretory organs, the degree of sensibility, the action of the moving power, &c. but how shall we attain this object, without an accurate and precise knowledge of these systems, their intimate structure, their elements, their figure, their extent and mass, their relation with one another; or with external bodies? Can we hope with our imperfect means, and on a subject involved in impenetrable darkness, ever to acquire that knowledge which is indispensible in order to arrive at accurate conclusions? The animal economy is subject to constant and invariable laws; but we can only hope to discover them by the aid of observation and experience, and in the body itself, where their power is displayed. It is seldom that we can make a happy application of mechanical principles to the living system. The circulation (not to depart from our subject) cannot be subject to hydraulic laws; the inequality of the capacity of the vessels, the most irregular angles, the most tortuous sinuosities, the greatest friction, &c. produce, according to the experiments of Spallanzani, scarcely a perceptible change on the circulation; a result which must appear strange, if we compare the vascular system to an hydraulic machine;

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but which can neither surprize nor astonish those who reflect, that all is animated in the human body: the most simple fibre, as well as the most complicated organ, and that the viscera which form a central point of vitality, are rather dependent on the parts with which they correspond, than a source supplying them with vital energy. Besides, the sect of mechanical physicians have in France but a very small number of followers:—If the revolution which chemistry experienced, had not been directed by men who united the greatest talents with the most profound knowledge of the science of man, the schools would still have resounded with the extravagances of Paracelsus and Willis, which some individuals endeavour in vain to re-establish.

Note 4, page 277. Such is the force of prejudice and hypothesis, that they often blind those who are most capable to detect and expose error. Spallanzani, who was assured by the most direct and positive experiments, that the circulation was carried on with quickness and regularity in vessels, separated from the heart by ligature or division, and that it was even maintained throughout the venous and arterial vessels, several hours and even whole days after the destruction of that viscus, nevertheless believed that the heart's action was the sole and only cause of the motion of the blood. I cannot more effectually refute this extraordinary opinion of the Professor, than by relating the experiments contained in the fourth Section of the third Dissertation, to which I refer the reader. But what are the principal sources which second the activity of the heart, in producing and carrying on the circulation? The most powerful, perhaps, consist in the

the contractile action of the venous and arterial vessels, which, according to John Hunter, and Scarpa, are of a fibrous texture, the structure of which is more dense and compact, in proportion to their distance from the heart; so that the blood, as it proceeds from this organ, and thus loses somewhat of the momentum received from it, finds in the vessels themselves, a power which repairs the loss of this momentum, diminishes the obstacles it encounters, and preserves and maintains its original velocity, amidst all the folds and convolutions of the ultimate capillary ramifications. That, at least, is the most probable consequence that can be deduced from this anatomical fact, which I have repeatedly had occasion to witness.

Note 5, page 295. Spallanzani does not pretend to deny the existence of the Lymphatics. Had he even done so, at the period when this work was written, he would have been supported by the opinion of the most celebrated anatomists. But the ingenious researches of Cruikshank, Mascagni, and several others, have now removed every doubt with regard to the existence of this order of vessels. With the Italians, they constitute a separate branch of instruction, from the study of the arteries and the veins; a practice which will, doubtless, be soon adopted in the universities of France. The reader will, perhaps, learn with pleasure, that the immortal professor of Sienna, is publishing an edition in 8vo, of his great and magnificent work, with two plates, which exhibit an outline of the principal divisions of the Lymphatic System. The first volume has already appeared: The second will contain an answer to the objections of Florian Caldani, (the nephew of the celebrated physiologist

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of that name) against the exclusive absorption of the Lymphatics.

Note 6, page 295. The microscopic observations of Spallanzani justify the supposition, that the arteries and veins contain, in addition to the blood, lymph, &c. an elastic and invisible gas, and the ingenious enquiries of Michele Rosa*, not only demonstrate its existence, but most clearly elucidate its mechanical and vital properties, the influence it has on the momentum of the blood, pulsation, respiration, and the proportions in which it is contained in the arteries and veins, &c. It remains to determine the nature of this air, in regard to which, without positive experiments, nothing can be formed except conjectures more or less plausible. The facility of collecting this gas, and analyzing its elements, the zeal and great knowledge of some celebrated men, who particularly apply themselves to this branch of chemistry, induce a hope, that they will soon enter upon these experiments; and I shall feel particular pleasure in having called their attention to a subject, the examination of which, must throw light upon sanguification and circulation.

Note 7, page 382. I was several times present while Spallanzani performed his experiments on languid circulation. When the death of the animal took place in a slow and gradual manner, the blood, at first, began to abate its current, it gradually lost its momentum, and

* Lettere Fisiologische del Cavaliere Michele Rosa, con osservazioni ed esperienze sul sanque fluido e rappresso, &c. del Pietro Moscati. Napoli, 1788. 2 vols. &c.

stopped

stopped almost in an insensible manner. But on employing the processes of Haller; that is, securing the mesentery with hooks, forcibly extending that membrane, and deranging the natural position of the vessels; the phænomena, stated by this physiologist, such as the intermission, oscillation, flux and reflux, of the venous and arterial fluid, proceed in alternate succession. But does it thence result, that the observations of Spallanzani destroy those of Haller? I do not think so. It would even appear to me, that they are not contradictory. The former shew, that when the principle of life is gradually extinguished, the circulation ceases insensibly; the latter prove, that the blood, before it stops, exhibits the most irregular appearance, when the animal perishes by a violent death, and the veins and arteries are forcibly stretched, compressed, and irritated. But, the sanguiferous vessels being affected with spasm or atony, in the greatest number of disorders which induce the dissolution of the animal machine, and likewise experiencing, sometimes, a very violent action, and at others a very feeble re-action, proceeding either from the contiguous parts, or from the fluids which circulate in their cavities, the experiments of Haller ought to be admitted in a more general and extensive sense, than those of the Professor of Pavia.

This retrograde motion of the blood towards the veins of the brain, explains the elevation and depression of that viscus during respiration: Haller, Spallanzani, and several other physiologists have remarked, a reflux of this fluid towards the descending *vena cava*; and Cotugno has very well elucidated the mechanism of this process, in in a paper inserted in the first volume of the Transactions of the Royal Academy of Naples.

Note 8, page 393. It deserves to be remarked, that cold-blooded animals survive, for several days, the destruction of the heart or brain; whilst, in warm-blooded animals, the slightest lesion of either of these viscera, produced the most dreadful consequences. This principally arises from the difference of connexion between the respective organic systems, and in these two classes of animals. In the first, the organs are not so intimately united. The fibres, the vessels, the nerves, and even the viscera, seem to exercise functions separate and distinct; having nothing in common but a mutual tendency to support and preserve the whole machine. In the second class, on the other hand, the organization, and action of these parts are more intimately connected, and have a greater dependence on each other. The heart cannot continue its motion, if the respiration stops: the stomach ceases to digest, if the brain be affected; the nerves suffer the most violent convulsions, if the circulation be disordered and irregular, &c. It is not easy to discover the cause of this difference of connexion. It may, perhaps, be found in the inseparable connexion of the circulation, with respiration in warm-blooded animals, and the almost entire separation of those two functions in those with cold-blood.

FINIS.

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