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THE

INSTITUTIONS

OF

PHYSIOLOGY,

TRANSLATED FROM THE LATIN

OF

PROFESSOR BLUMENBACH,

With Additional Notes,

ILLUSTRATIVE AND EMENDATORY.

By ceaseless action all that is subsists,
Constant rotation of the unwearied wheel
That nature rides upon, maintains her health,
Her beauty, her fertility. She dreads an instant's pause,
And lives but while she moves.

COWPER'S TASK.

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THE

TRANSLATOR'S PREFACE.

THE fame of Blumenbach's learning and talents is well established, and the Institutions of Physiology are in no respect unworthy of their author. Nearly unencumbered by hypothesis, and perfectly free from extraneous matter, they contain more solid information than most other medical works of equal magnitude, and deserve the diligent perusal of every student. No apology, therefore, is required for undertaking to translate them into English. Whether the Translator has done justice to his author, he cannot determine, but he has rendered every passage as literally as the idiom of the languages would allow. The Notes are as concise as

possible, and added only where the text was obscure from brevity, or imperfect from the want of knowledge, which, since the last edition, printed in 1810, has been obtained by the labour of physiologists. Should they be favourably received, the Translator will venture to enlarge them in a subsequent edition.

Quæramus optima, nec protinus se offerentibus gaudeamus, adhibeatur judicium inventis, dispositio probatis.

QUINTILIAN.

PREFACE

TO THE

LAST EDITION.

WHENEVER my booksellers have informed me, that a new edition of any of my works was required, I have always gladly seized the opportunity of correcting inaccuracies, arising either from carelessness, or the imperfection of human nature; of adding in some places, and altering in others; in short, of sending forth the production of my abilities in a more finished state.

In preparing for the press this new edition of my Institutions of Physiology, the same anxious wish has been considerably heightened by the importance of the subject, and by the approbation evi-

dently bestowed upon the last edition, by its translation into our own language, into Spanish, French, English, Dutch, and Russian, not to mention other proofs of its favourable reception. I have endeavoured, therefore, to enrich it not so much with an addition of pages, as of various matter; to arrange the heads in a more natural order; and to render the whole as useful to students as possible.

September 10, 1810.

PREFACE

TO THE

FIRST EDITION.

THE Author was induced to write these Institutions by the same reasons on account of which Boerhaave, and after him Haller, composed their Compendiums of Physiology.

The former says, " that a teacher succeeds better in commenting upon his own thoughts, than in attempting to enlarge upon a work written by another:—that his doctrine will be clearer, and his language generally more animated."*

* Pref. to the Instit. Medic.

The latter, "Although he formerly used Boerhaave's work as a text-book, he afterwards lectured upon one written by himself, because, since the time of Boerhaave, anatomy had been so improved as to become quite a new science."*

What Haller said at that period respecting anatomy, will be allowed to apply much more forcibly at present to physiology, by any one who considers the most important part of the science,—the principal purpose of respiration, animal heat, digestion, the true nature and use of the bile, the function of generation, &c.

More, therefore, must be ascribed to the age than to the author, if in these Institutions, after so many modern physiological discoveries, he delivers doctrines more sound and natural, than it was in the power of his predecessors to deliver.

Whatever he can claim as his own, whether

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* Pref. to the Prim. lin. Physiol.

really new, or only explained or noticed in a new manner, will be easily discovered by the learned and impartial reader; especially from the notes, in which he has treated some subjects rather more minutely than, in the text, was compatible with the conciseness of his plan.

He has been at great pains in arranging the subjects, so that the sections might succeed naturally and easily, and, as it were, arise one out of another.

He has not quoted a dry farrago of books, but a select number. In doing this, he has wished both to point out to students some excellent authors not commonly known, but who have professedly treated on particular heads of the subject, and to excite a fondness for other studies besides medicine, which he thinks are not applied to physiology as they deserve*.

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* As these are extremely numerous, and for the most part inaccessible to students in this country, the translator has not thought right to enlarge the work by their insertion.

His grand object has been to deliver, in a faithful, concise, and intelligible manner, the principles of a science inferior in beauty, importance, and utility, to no department of medicine, if the words prefixed by the immortal Galen to his Methodus Medeni, are true,—" The magnitude of a disease is in proportion to its deviation from the healthy state; and the extent of this deviation can be ascertained by him only who knows perfectly in what the healthy state consists."

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INSTITUTES

OF

PHYSIOLOGY.

SECT. I.

OF THE LIVING HUMAN BODY IN GENERAL.

1. IN the living human body, regarded as a peculiar organization, there are three objects of consideration*.

The materials of its subsistence, afforded by the fluids;

The structure of the solids, containing the fluids;

Lastly, and principally, *the vital powers*, by which the solids are enabled to receive the influence of the fluids—to propel the fluids—and perform various other motions;

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* Thus, long ago, the author of the book, generally included among the writings of Hippocrates, Epidemic VI. Lect. 8. §. 19. "Those things which contain, are contained, or moved in us with force, are to be considered." This celebrated passage gave origin to the work of Abr. Kaau Boerhaave, entitled, "Impetum faciens dictum Hippocrati per corpus consentiens." L. B. 1745. 8.

and which, as they, in a certain sense, constitute the essence of the living machine in general, so also are of very different orders: some being common to animals and vegetables, some peculiar to animals, and intimately connected with the mental faculties.

2. But these three, although really distinct, and therefore distinctly considered by us, are so closely related in the living system, (the phenomena, conditions, and laws of whose functions, in the healthy state, are the object of physiology,) that no one can be contemplated, but in its relation to the rest.

For the materials of the body, although originally fluid, are naturally disposed to become solid; and, on the other hand, the solids, besides having been formed from the fluids, abound, however dry they may appear, in various kinds of fluid constituents, both liquid and aeriform: lastly, it may probably be affirmed, that no fibril, during life, is destitute of vital power.

3. We shall now examine each of these separately; and first, the materials afforded by the fluids, which form both the fundamental and most considerable portion of our bodies*.

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* The great preponderance of the fluids is strikingly exemplified in an entire, but perfectly dry mummy of an adult Guancha, one of the original inhabitants of the island of Teneriff. It was sent to my anatomical museum by the illustrious Banks; and though all its viscera and muscles are preserved, does not exceed 7½lbs.

SECT. II.

OF THE FLUIDS IN GENERAL, AND PARTICULARLY THE BLOOD.

4. THE fluids of the body may be conveniently reduced to three classes.

A. The crude; viz. the chyle, contained in the primæ viæ, and destined to become blood; also, matters absorbed on the surface, and destined to be conveyed to the chyle.

B. The blood itself.

C. Those secreted from the blood, whether inert and excrementitious, like the urine; or intended for certain purposes in the economy: the latter may be permanently liquid, as the bile—or disposed to solidity, as the osseous and other plastic juices.

5. Of the first and third of these classes we shall hereafter speak, in treating of chylosis, secretion, and the other functions to which each fluid appertains. At present our attention shall be devoted to the blood, the chief and primary fluid—the vehicle of those successions of oxygenous (A) and carbonaceous particles, which cease only with life—the nourisher of the frame—the source of almost every fluid—that into which the crude fluid is converted, and from which all the secretions are derived; and which, with the exception of some exsangueous parts, as the epidermis, the arachnoid, the amnion, &c. the vitreous substance of the teeth, the body of the chrystalline lens, &c. is universally diffused through the system, in

various proportions, indeed, according to the various natures of the similar parts, to use the language of the ancients*, v. c. abundantly in the muscles and glands, sparingly in the tendons and cartilages†.

6. The blood is a peculiar fluid, of a well known colour, and remarkable odour; its taste rather salt and nauseous; its temperature about 96° of Fahrenheit; glutinous to the touch; its specific gravity, though different in different individuals, may be generally estimated as 1050 (B), water being 1000; when fresh drawn, and received into a vessel, it exhibits the following appearances.

7. At first, while still warm, it emits a vapour, which has of late been denominated an animal gas, and shewn to consist of hydrogen and carbon, suspended by caloric‡. This, if collected, forms drops resembling dew, of a watery nature, but endowed with a nidorous odour,

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* They divided the body into similar, or homogeneous parts, as the bones, cartilages, muscles, tendons, &c.; and dissimilar, composed of the similar, as the head, trunk, limbs, &c.

† Physiologists have variously estimated the quantity of the blood, in a well formed adult. Allen, Mullen, and Abildgaard, make it scarcely more than 8 pounds; Borelli, 20; Haller, 30; Hamberger, 80; Keil, 100. The former are evidently nearer the truth.

‡ The elements of aeriform fluids of course exist in the blood; not, however, in the elastic state, as was formerly believed. By experiments made during the year 1782, upon some mammalia, I found, that a small portion of the purest air infused into the jugular vein, excited palpitations, drowsiness, convulsions; and if the quantity was rather increased, even death ensued. *Medic. Biblioth.* vol. i. 177. The illustrious Bichat relates the same effects in his experiments. *Journal de santé, &c. de Bourdeaux.* T. 11. 61.

most remarkable in the blood of carnivorous animals, peculiar, and truly animal. Much of this watery liquor still remains united with the other parts of the blood.

8. In the mean time the blood, when its temperature has fallen to about 78°, begins to separate into two portions. A coagulum is formed, from the surface of which exudes a fluid of a yellowish slightly red colour, denominated *serum*. The more abundantly this exudes, the greater is the contraction of the glutinous coagulum, which has received the appellations of *crassamentum;* from some resemblance to the liver, in colour and texture, of *hepar sanguineum;* of *placenta;* and, from the circumstance of its being surrounded by the serum, of *insula*.

9. The crassamentum may, by agitation, or repeated ablution, be easily separated into two constituent parts; into the cruor, which imparts to the blood its purple colour, and by washing forsakes the *lymph*, called, from its greater solidity, the basis of the crassamentum; the stronger affinity of the lymph for the cruor than for the serum, is proved by the necessity of violence to effect their disunion (C). By the removal of the cruor, the lymph becomes gradually paler, till it is at length merely a white tenacious coagulum.

10. Besides the watery fluid first mentioned, these are the three constituents of the blood, viz. the *serum*, the *cruor*, and the *lymph:* we shall presently treat of each more particularly. These, however, while recent, and in possession of their native heat, are intimately mixed, and form an equable, homogeneous fluid. Their relative proportion is astonishingly diversified, according to age, temperament, diet, and similar circumstances, which constitute the peculiar health of each individual.

11. The *serum* is a fluid, *sui generis;* the chief cause of the viscidity of the blood, and easily separable by art into different constituent principles. If subjected to a temperature of 150° Fahr. a portion is converted into a white, scissile substance, resembling the boiled white of an egg: the rest, besides the watery fluid so often mentioned, exhibits a turbid fluid of a gelatinous, or rather mucous nature, which on cooling appears a tremulous coagulum. The serum is remarkable for containing soda (D).

12. The cruor is marked by many singularities, both in its colour and the figure of its particles. It consists of globules, which in recent blood are of a constant form and size, and said to be $\frac{1}{3300}$ of an inch in diameter. Their form has been a subject of dispute; but I am disposed to consider it as much more simple, than some writers of great celebrity have imagined. I have always found it globular; and could never discover the lenticular shape, which some have asserted that they remarked.

It has been likewise advanced, that the globules change their form, while passing through a vessel of smaller capacity; that, from being spherical, they become oval; and when they have emerged into a vessel of larger area, that they again resume their globular shape. This, although I would by no means deny it, I cannot conceive to occur during the tranquil and healthy motion of the blood, but should refer it to a spasm of the small vessels. Their globular figure can be seen in a living animal only, or in blood recently drawn: for they soon become a shapeless mass, resembling serum in every circumstance, excepting colour.

13. Their colour is red, and from it is derived the colour of the blood. In intensity it varies infinitely;

paler in animals which have been poorly nourished, or have suffered from hœmorrhage; more florid, oxygenated*, (arterial, to use the common phrase) if exposed to atmospheric air, or more especially, if to oxygen; darker carbonized (in common language, venous) if exposed to carbonic acid gas, or to hydrogen. The redness is most probably to be ascribed to the oxide of iron †, the quantity of which, though minute, has been most variously estimated (E).

14. The last principle of the blood to be noticed, is the plastic lymph, formerly confounded with the serum. This has been called the basis of the crassamentum, the glutinous part, the fibre or fibrous matter of the blood, and, like the caseous part of milk, and the gluten of vegetables, been discovered to abound in carbon and azote (F).

15. It is properly denominated plastic, because it affords the chief materials from which the similar parts, especially the muscles, are immediately produced; it nourishes the body, repairs wounds and fractures in an extraordinary manner, fills up the areæ of large divided blood

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* Unwilling as I am to follow the example of those, who, especially in modern times, delight in changing the terms of science, I cannot but think that the words oxygenized and carbonized may be advantageously substituted for arterial and venous: because arterial blood is contained in some vessels called veins, v. c. the pulmonary and umbilical; while, on the other hand, venous blood is contained in the pulmonary and umbilical arteries. In the same manner, the veins of the chorion in the incubated egg contain arterial, the arteries venous blood.

† By Wells, Philos. Trans. 1797, it is ascribed to the peculiar fabric of the globules, and its various degrees and changes simply to the reflection of light.

vessels, forms those concretions which accompany inflammations*, and that remarkable deciduous membrane, found in the recently impregnated uterus, for the attachment of the ovum.

16. Thus much have I said, respecting the constituent parts and nature of the blood, the most important fluid of the animal machine,—a fluid, which excites the heart to contraction; which distributes oxygen to every part; and conveys the useless carbon to the excretory vessels, giving rise, by this change, to animal heat; which supplies originally the matter of the solids, and afterwards their nourishment; from which all the fluids, with the exception of the crude, are secreted and derived. Of the multifarious importance of the blood, I shall speak particularly hereafter.

NOTES.

(A) THE blood is not at present believed to absorb any oxygen, during respiration.

(B) Haller states it to be 1527.

(C) There is every reason to believe the cruor merely suspended. The serum easily separates on the coagulation of the lymph, because much lighter; the cruor being more nearly of

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* Such are those spurious membranes found exuded on the surface of inflamed viscera, v. c. connecting the lungs and pleura after peripneumony; and forming tubes within the bronchiæ after croup: such also are those called, after their inventor, Ruyschian, and effected by stirring fresh blood about with a stick.

the same specific gravity as the lymph, does not fall to the bottom before the lymph coagulating envelopes it, and prevents its separation: but if the lymph coagulates slowly, as in the phlogistic diathesis, the greater specific gravity of the cruor detaches it from the lymph. Berzelius even believes the lymph to be chemically dissolved by the serum, while the cruor is mechanically suspended in this solution.

(D) The coagulable part of serum is albumen; that which remains fluid is called serosity, and consists, according to Dr. Bostock, of mucus holding soda, muriate of soda, phosphate of soda, and phosphate of lime in solution. Sulphur appears to be a constituent part of albumen.

(E) It has been generally supposed, that iron existed in the blood as a subphosphate. Berzelius, in his Animal Chemistry, informs us, that serum, though capable of dissolving a small portion of the salts of iron, does not acquire a red colour by their addition; and that he has never detected iron nor phosphate of lime in the blood, though both are so abundant in its ashes; and concludes, that the "blood contains the elements of these salts, united in a manner different from their combination in the salts." The cruor contains likewise albumen and soda.

(F) Oxygen also exists in fibrin. Albumen contains the same elements, but has a greater proportion of oxygen.

SECT. III.

OF THE SOLIDS IN GENERAL, AND OF THE MUCOUS WEB IN PARTICULAR.

17. THE solids are derived from the fluids. In the first rudiments of the gelatinous embryo, they gradually commence, and differ infinitely in their degrees of cohesion, from the soft and pulpy medullary matter of the brain, to the vitreous substance of the corona of the teeth.

18. Besides the gelatinous (11) and mucous (15) parts of the solids, earth enters more or less into their composition, and is principally lime united with phosphoric acid. The bones possess this in the greatest abundance, particularly in advanced age, whereas in childhood the gelatinous matter abounds.

19. With respect to texture, a great part of the solids consist of fibres more or less parallel. This may be observed in the bones, especially of fœtuses,* in the mus-

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* The parallel and reticulated bony fibres are most striking in the radiated margins of the flat bones, as we find them in heads much enlarged by hydrocephalus. I have a preparation in my museum, where on the sphenoid angles of the parietal bones, the fibres are an inch in length, distinct and delicate. The hardest parts, the bony and vitreous part of the teeth, exhibit a structure similar to that which in the zeolite, malachite, hematite, &c. all mineralogists call fibrous.

cles, tendons, ligaments, aponeuroses, and in certain membranes, as the dura mater.

20. In other parts no fibres can be detected, but the texture is peculiar, called parenchyma, since the time of Erasistratus, and differing in different viscera, especially the secreting; of one kind in the liver, of another in the kidneys.

21. But in all the structures, whether fibrous or parenchymatous, there is interwoven a general mucous web, commonly but improperly styled cellular, because it rather is continuous, equal, tenacious, ductile, sub-pellucid, and glutinous. By handling, it is easily converted into a cellular or vesicular membrane; but demands a place among the most important and remarkable constituents of the body.

22. For, in the first place, many solid parts, **v. c.** most membranes and cartilages, may by maceration be resolved into it alone. With some it is so intimately united, as to afford a receptacle and support for other constituents: v. c. the hardest bones consisted at first of cartilage, which was originally condensed mucous membrane; but since become distended by the effusion of bony matter into its substance, which is rendered more lax and cellular. In fact, it is universally present in the solids, if we except the epidermis, nails, and hairs, and the vitreous corona of the teeth, in which I have never been able to discover it by employing the strongest acid.

23. To the muscles and membranes especially it serves for separation from other parts: to the vessels and nerves for support; and to every part it acts as the common medium of connexion.

24. From these facts, two inferences may be drawn. First: That this membrane is so fundamental a constituent

of our structure, that, were every other part removed, the body would still retain its form.

Secondly: That it forms a connexion between all parts of the system, however different from each other in nature, or remote in situation: a circumstance worthy of attention, as putting an end to the disputes respecting the continuation of membranes, and affording an explanation of many morbid phenomena.

25. As most of the solids owe their existence to this membrane, so again its origin is derived from the lymph of the blood. I have found the lymph changed into this membrane, when transuded on the surface of inflamed lungs, and by forming false membranes, it afterwards unites these organs to the pleura.

26. I shall now consider some varieties of this membrane. In general, it is more delicate, cæteris paribus, in man than in animals; a distinguishing prerogative, by which our sense is rendered more delicate, and our motions and other functions more perfect. Among different individuals, it varies much in laxity and firmness, according to age, sex, temperament, mode of life, climate, &c.

Finally, it varies in different parts; more lax in the palpebræ and preputium, and behind the frænum of the tongue; less so around the ears.

27. Besides the purposes before mentioned, it is destined for the reception of several fluids. Its chief use in this respect is to receive that watery halitus which moistens and lubricates every part. This, when formed by the blood vessels, it imbibes like a sponge, and delivers over to the lymphatics, thus constituting the grand connexion between these two systems of vessels.

28. In the eye, existing as the vitreous membrane, it contains the vitreous humour: in the bones, as the medullary membrane (improperly denominated internal periosteum), the marrow; in soft parts, it is in great abundance, and contains the rest of the fat, of which I shall speak hereafter.

SECT. IV.

OF THE VITAL POWERS IN GENERAL, AND PARTICULARLY OF CONTRACTILITY.

29. HITHERTO I have spoken of the solids, as the constituents of the system; now I shall view them as endowed with vitality, capable of receiving the agency of stimuli, and of performing motions.

30. Although vitality is one of those subjects which is more easily known than defined, and usually indeed rendered obscure rather than illustrated by an attempt at definition, its effects are sufficiently manifest and ascribable to peculiar powers only. The epithet vital is given to these powers, because on them so much depend the actions of the body during life, and of those parts which, for a short time after death, preserve their vitality, that we cannot refer them to any qualities merely physical, chemical, or mechanical.

31. The latter qualities, however, are of great importance in our economy. By physical powers, dependent on the density and figure of the humours of the eye, the rays of light are refracted to the axis; by mechanical, the epiglottis is elastic; by chemical affinity, the changes of respiration are effected. But the perfect difference of these powers from those which we are now about to examine, is evident from the slightest comparison of an organized economy with any inorganic body, in which these inanimate powers are equally strong.

32. Indeed the vital powers are most conspicuously manifested, by their resistance and superiority to the others; v. c. during life, they so strongly oppose the chemical affinities which induce putrefaction, that Stahl and his followers referred their notion of life to this anti-septic property;* they so far exceed the force of gravity, that, according to the celebrated problem of Borelli, a dead muscle would be broken asunder by the very same weight, which, if alive, it could easily raise.

33. As on the one hand, the vital properties are completely different from the properties of dead matter, so, on the other, they must be carefully distinguished from the mental faculties which will form the subject of the next chapter: between them, however, there exists an intimate and various relation observable in many phenomena, but especially in the diversity of temperament.

34. The vital energy is the very basis of physiology, and has therefore been always noticed, though under different appellations. The titles of impetum faciens, innate heat, archæus, vital spirit, brute life, head of the nervous system, active thinking principle, vital tonic attraction, have been bestowed upon it by different authors.

35. Nor has there been less variety in the notions and definitions to which it has given rise; though in this one point all have agreed,—that its nature and causes are most obscure.

36. As to the question so long agitated by physiolo-

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* Life formally is nothing more than the preservation of the body in mixture, corruptible indeed, but without the occurrence of corruption. STAHL.

What we call life is opposite to putridity. J. JUNKER.

gists, whether the diversity of the phenomena exhibited in the similar parts of the living solid, are to be attributed to modifications only, or to distinct species of the vital energy, we think it best to establish distinct orders of the vital powers, according to the variety of phenomena by which they are manifested.

37. These phenomena are threefold. Organic *formation* and increase; *motion* in the parts when formed: *sensation* from the motion of certain similar parts.

38. The first requisite involved in the name and notion of an organized body, is a determinate form designed for certain ends. That species, therefore, of the vital powers is most general, which produces the genital and nutritive fluids, and prepares them for organic nature. This species we have denominated the *nisus formativus*, since it is the source of all generation, nutrition, and reproduction, in each organized kingdom.

39. Those vital powers, which are manifested by *motion*, properly so called, in parts already formed, may be divided into common and proper. The common are those belonging to similar parts, which are widely distributed; v. c. contractility to the mucous structure; irritability to the muscular fibre. The proper are those possessed only by individual organs, whose motions are peculiar and characteristic.

40. *Contractility* is as generally distributed as the mucous structure, which it may be said to animate; and therefore would be called not improperly perhaps the *vis cellulosa*. It is characterized by a simple and not very sensible effort to contract and react upon its contents, especially upon its source of moisture,—the serous vapour, and to propel this into the lymphatic system.

41. *Irritability*, I mean the irritability of Haller, is

peculiar to the muscles, and may be called the *vis muscularis*. It is marked by an oscillatory or tremulous motion, distinguished from the action of simple contractility, by being far more permanent, and by occurring far more easily on the application of a stimulus.*

42. Such are the common moving vital powers. But some organs differ from the rest so much in the singularity of their structure, motions and functions, as not to come under the laws of the common orders of vital power. We must, consequently, either reform the characters of these orders, institute new ones, and extend their limits, or, till this be done, separate these peculiar motions from the common orders, and designate them by the name of *vitæ propriæ*. As examples may be adduced, the motions of the iris ; the erection of the nipple; the motions of the fimbriæ of the Fallopian tubes; the action of the placenta and womb during labour, and probably the greater part of the function of secretion.

43. So much in regard to the vital powers displayed by motion. (37, 39, 42.) We have now to speak of *sensibility*, which is peculiar to the nervous medulla communicating with the sensorium. It bears the title of vis nervea, and is the cause of perception when irritation is excited in parts to which it is distributed.†

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* That Haller and Theoph. de Bordeu did not form a just conception of the vital power, will be evident from the latter's *Recherches sur le tissu Muqueux*, Par. 1767—8, and the dissertation of the former on Irritability in the Dictionaire Encyclopedique d'Yverdun. T. xxv.

† Others have attributed many of these phenomena to an orgasm, to use an old expression, struggling from the centre to the circumference, lately designated by the term vital turgor.

44. The order which we have followed in enumerating the vital powers, is that which spontaneously occurs both during and after our formation.

The *nisus formativus* must take place before we can ascertain the existence of the new conception. Then contractility must be exerted in the gelatinous substance of the embryo.

When the muscular fibres are produced, they acquire irritability.

In those few organs whose motions cannot properly be referred either to contractility or irritability, there must next exist the *vita propria.*

Finally, after birth, sensibility is superadded.

45. Similar also is the order, according to which the vital powers, both common and proper, are distributed to the organized bodies of each kingdom. For, the formative power must be most universal; without it indeed organization cannot be conceived to exist.

Contractility likewise is common to each kingdom.

Irritability and sensibility, in the sense above explained, are peculiar to animals.

Lastly, the vita propria is variously observable in some organs, particularly the generative, both in animals and certain vegetables.

46. It is scarcely necessary to remark, that most of these modes of vital energy, though necessarily distinguished into orders, are intimately connected; v. c. the mucous membrane, forming the basis and seat of contractility in so many organs, is interwoven also with the irritable muscular fibres and the sensible nerves.

47. Whatever may have been the opinions of physiologists respecting the difference or identity of the vital powers, it is universally agreed that they exist in the similar solid parts, as the ancients called them, of which the

organs or dissimilar parts are composed. But it has been disputed, and particularly of late, whether vitality is peculiar to the solids, or common also to the fluids; and the latter being granted, whether or no the blood alone is so endowed.

48. As to the first question, the natural history of each organic kingdom, as far as it has hitherto been cultivated, abundantly shows that those living parts, however delicate, of all known animals and vegetables, are solid; a circumstance necessarily implying a figure determinate and destined for certain uses. For, not to speak of entire animals, (which, however simple, as worms, are nevertheless supplied with enveloping membranes) the newly laid egg, though at first sight merely fluid, on a more careful examination is discovered to consist of different membranes, of the halones, the cicatricula, &c.

Humidity is indeed necessary in the living solid, for the exertion of vitality. But that vitality exists in the solid, as solid, is proved by the well known instances of animalcules and the seeds of plants, in which, although long dried, the vital principle is so entire, that they again live and germinate.

49. With respect to the supposed exclusive vitality of the blood, I candidly confess that no argument has been adduced in its favor since the time of Harvey, which might not, I think, be more easily, simply, and naturally explained on the contrary supposition.

For example, the incorruptibility of the blood during life, is far more explicable from the perpetual changes which it undergoes, especially in respiration.

That the blood is the material from which the living solids are produced, is no stronger an argument of its vi-

tality, than the formation of nymphææ, and so many other remarkable plants would be for the vitality of water.

It is difficult to comprehend how the coagulation of the lymph of the blood can demonstrate its vitality. The organic formation of the lymph in generation, nutrition, and reproduction, depends not upon the lymph itself, but upon the action of the nisus formativus. (B)

50. Those who have contended* that the blood acquires in the lungs from the air a certain principle to be universally distributed during circulation, for the purpose of imparting motion, &c. to the organs, were right, if they regarded that principle (analogous to oxygen) (C) as the stimulant of the living solid; wrong, if they regarded it as vitality itself.

51. For it is on all hands agreed, that no motion occurs but upon the action of stimuli, to receive which action the vital powers are naturally adapted and intended.

52. These stimuli, however multifarious, are conveniently reduced to three classes; chemical, mechanical, and mental. For the present, we shall say nothing of their various modes of action; in some instances direct, in others indirect by sympathy and reaction. It is sufficient to cite a few examples of functions, to which each class of stimuli conspire: such is the increased secretion of tears,

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* V. C. Dan. Bernouilli de Respiratione, Basil, 1721.

"Respiration supplies a very subtle air, which, when intimately mixed with the blood, greatly condensed, conveyed to the moving fibres, and allowed by the animal spirits to exert its powers, inflates, contracts, and moves the muscles, and thus promotes the circulation of fluids, and imparts motion to mobile parts."

saliva, bile, &c. and the venereal turgescence of the genitals.

53. If the nature of stimuli is infinitely various, no less so are their effects, according to their nature, intensity, or continued and repeated application to the living solid. Hence they are generally divided into exciting and depressing.

54. The power of certain stimuli in increasing the effects of others, is very remarkable: v. c. the power of caloric, upon which probably depends the influence of climate on the temperament. That of joy, a most energetic mental stimulus, is similar. Likewise perhaps that of oxygen, (50) by whose chemical stimulus the vital powers, particularly irritability, are greatly excited, and more disposed to react upon the impulse of other stimuli.

55. Not less considerable than the variety of stimuli, is that more minute discrepancy of the different organs, and of the same organs in different individuals, according to age, sex, temperament, idiosyncrasy, habit, mode of life, &c.; to this is owing the diversified effects of the same stimuli upon different organs, and upon the same even in different individuals: the English have lately given it the appellation of specific irritability.

56. Lastly, the influence of stimuli by means of sympathy, is very extraordinary: by its means, if one part is excited, another, frequently very remote, consents in feeling, motion, or some peculiar function.

The primary and most extensive cause of sympathy is the nerves, and indeed chiefly the sensorial reaction; so that if one nervous portion is excited, the sensorium is affected, which reacting on another nervous portion, draws it into consent with the first, although there exist no immediate nervous connexion. Such is the sympathy of the iris, when the retina is stimulated by light; and of the dia-

aphragm during sneezing, when the Schneiderian membrane is irritated.

There are other examples of sympathy, in which the nerves, if they have any, have a more remote and accessory share* ; among these must be placed the sympathy along the blood vessels, strikingly instanced between the internal mammary and epigastric arteries in advanced pregnancy : that along the lymphatic vessels, also most remarkable during pregnancy and suckling : and again, that dependent on analogy of structure and function, v. c. the sympathy of the lungs with the surface and intestines.

57. The vital powers will be hereafter separately considered, under the distinct heads of our subject. The nisus formativus under the head of Generation ; irritability under that of the Muscles ; sensibility under that of the nervous System ; the vita propria when occasion requires.

58. Besides our former brief remarks (40) upon contractility, a few more minute will at present not be misplaced.

It prevails universally, wherever the mucous tela is discovered.

It is consequently most abundant in parts destitute of proper parenchyma, but composed almost entirely of mu-

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* Consider the constant sympathy of heat between certain parts of some animals, v. c. of the hairs with the fauces, in rabbits, sheep, dogs, &c. of the feathers with the covering of the bill and feet in varieties of the domestic duck. That many such instances are not referable to the influence of nerves, I contended in my *comm. de Motu iridis*, p. 12, et seq. and also in my work de Generis humani varietate nativa, p. 364, et seq.

cous tela, v. c. in certain membranes: for no one will deny their contractility, who reflects upon the spastic motions of the dartos, the urethra, or of the gall bladder, which during death is always closely contracted upon any calculi it contain.

It appears also in those viscera which consist chiefly of this tela, v. c. in the lungs, whose external surface (C) I have found on living dissection very contractile; but by no means, as Varnerius asserts, truly irritable. (D)

The presence of contractility even in the bones is demonstrated, in the shrinking of the alveoli after the loss of the teeth, and in the process of necrosis, by which, the new bone, when the dead portion is extricated from its cavity, contracts to its natural size and figure.

The vitreous substance of the teeth being destitute of this tela (22) possesses no contractility, as I think appears from the circumstance of its not shrinking, like the alveoli, if a portion is separated by caries or fracture.

59. The contractility of the mucous tela is the chief cause of strength, health, and beauty; since on it depends the vital elasticity and fulness*, and indeed the tone of parts, so elegantly described by Stahl. By its means, the mucous tela, to mention one only of its functions, absorbs, during health, the serous fluid (27) like a sponge, and propels it into the lymphatic vessels: in disease, on the con-

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* Hence after death, especially in young subjects full of juices, the back, loins, and buttocks, having for some time lost their vital tone, are, if the body is supine, depressed and flattened by the superincumbent weight, which now is not resisted: this appearance I regard among the indubitable signs of death.

trary, having lost its tone, it is filled with water, giving rise to œdema and similar cachexies.

60. Finally, the great influence of contractility in producing the peculiar constitution and temperaments of individuals, is manifest from its universal presence, its close union with the other vital powers, and from its infinite modes and degrees in different persons.

NOTES.

(A) The word life should be regarded merely as an expression of a fact. In this point of view it may be as easily defined as any other expression. By life we generally mean, the circumstance of organized matter increasing or decreasing by inherent powers; preserving its particles in such chemical relations, as to prevent other chemical relations from inducing putridity; preserving, or greatly tending to preserve, a regular temperature distinct from that of the surrounding medium; moving independently of mere impulse, attraction, or repulsion; generating certain well known matters, difficult or impossible to be produced artificially.

The essential cause of all this is not an inquiry for philosophy, any more than the essence of mind, or of matter, of caloric, gravitation, &c. The object of philosophy is to observe facts, and discover the laws of their occurrence.

We may indeed inquire, whether certain facts are in their nature distinct or identical; and whether they depend on substances or properties. Thus galvanism is proved to be identical with electricity, and light is generally regarded as a substance.

Both these inquiries in regard to life, have hitherto proved

fruitless; the latest work on this subject, is Mr. Abernethy's Lecture on Life, delivered to the London College of Surgeons; life is there represented as very analogous to electricity, and, granting electricity to be material, as being very probably a subtle matter. The strictures made on this lecture in the last number of the Edinburgh Review are well worth reading, though indeed given in too vulgar and uncandid a manner for so learned and philosophical a journal.

(B) This is not very intelligible. The fluid, in these examples of generation, nutrition, and reproduction, cannot but be endowed with life.

(C) Our author here, as in Par. 135, does not mean exactly the surface of the lungs, but the pulmonary portion of the pleura.

(D) Blumenbach very properly views the pleura and other serous membranes as condensed cellular substance, that is, as a substance not originally cellular and now condensed, but of the same nature as the cellular substance, though much more compact. Vid. Bichat's Traitè des Membranes.

SECT. V.

OF THE MENTAL FACULTIES.

61. MAN, whom we have found possessed of a body, answering completely both in matter and texture, as well as vital powers, the purposes of its formation, is endowed likewise with a mind, a "divinæ particula auræ," intimately connected with the body, and developing by education and exercise various kinds of faculties, which we shall concisely enumerate, as far as they belong to our subject.

62. The sensibility of the nerves, mentioned above among the vital powers, (43) constitutes, as it were, the medium which propagates the impressions of stimuli upon sensible parts, and especially upon the organs of sense, (to be hereafter examined) to the sensorial portion of the brain, in such a manner that they are perceived by the mind.

63. The mental faculty to be first enumerated, and indeed to be placed at the bottom of the scale, is the faculty of *perception*, by means of which the mind takes cognizance of impressions made upon the body, and chiefly upon the organs of sense, and becomes furnished with ideas.

64. This faculty is assisted by another of an higher order, *attention*, which so directs the mind when excited to any idea, that it dwells upon that idea alone, and surveys it fully.

65. To preserve and recall the marks of ideas, is the office of *memory*, that part of the mind, which, in the language of Cicero, is the guardian of the rest.

66. *Imagination**, on the contrary, is that faculty of the mind, which represents not merely the signs, but the very images of objects in a most lively manner as if before the eyes.

67. *Abstraction* forms general notions more remote from sense.

68. *Judgment* compares and examines the relations of the ideas of sense, and of general notions.

69. Lastly *reason*, the most noble and excellent of all the faculties, draws inferences from the comparisons of the judgment.

70. The combination of these, constitutes the intellectual faculty; but there is another order, relating to appetency, to take the word in its most extensive meaning.

71. For since we are impelled by various internal stimuli to provide food and other necessaries, and also to satisfy the sexual instinct, and are impelled the more

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* The difference, analogy, and relation of memory and judgment, have given rise to various controversies. Some celebrated psychologists have included both under the word imagination taken in its most comprehensive sense, and have divided it into two species; *memory*, representing former ideas, and the *facultas fingendi*, representing such ideas only as are formed by abstraction. They again divide memory into sensitive (imagination in a stricter sense) and intellectual.

Their *facultas fingendi*, they also subdivide into intellectual (more excellent), and *phantasy* obeying mechanical laws. Feder Grundsätze der Logick und Metaphysick. Gotting. 1794, p. 20.

violently, in proportion as imagination inflames our wishes; *desires*, properly so called, are thus produced; and if, on the other hand, the mind is weary of unpleasant sensations, *aversions* occur.

72. Finally, that faculty which selects out of many desires and aversions, and can at pleasure determine to perform functions for certain purposes, is denominated *volition.*

73. Our order of enumeration corresponds with that of the development of the faculties, and with the relation in which those termed brute, common to man and animals, and those more or less peculiar to man, stand to each other.

SECT. VI.

OF HEALTH AND HUMAN NATURE.

74. SINCE health, which is the object of physiology, depends upon such an harmony and equilibrium of the matter and powers of the system, as is requisite for the due performance of its functions, it is very evident how the four principles examined above, contribute to its support.

75. Fluids properly prepared are the first requisite; in the next place, solids duly formed from the fluids; then the invigorating influence of the vital powers; lastly, a sound mind in this sound body.

76. These four principles act and react perpetually upon each other; the fluids are stimuli to the solids: these again are calculated by their vital powers to experience the influence of these stimuli, and react upon them. In reference to the intimate union of the mind with the body, suffice it at present to remark, that it is far more extensive than might at first be imagined. For instance, the influence of the will is not contained in the narrow limits of those actions designated voluntary in the schools of physiology; and the mind, on the other hand, is influenced by the affections of the body, in many other ways besides the perceptions of sense.

77. From the endless variety and modification of the conditions belonging to these four principles, it may be

easily understood, how great latitude must be given to the notion of health. For since, as Celsus long ago observed, every one has some part weaker than the rest, Galen may in this sense assert with truth, that no one enjoys perfect health. And even among those whom we commonly regard as in good health, this is variously modified in each individual.

78. Upon this modification is founded the difference of temperaments; or, in other words, of the mode and aptitude of the living solid* in each individual, to be affected by stimuli, especially the mental; and again, of the mental stimuli, to be excited with greater or less facility.

79. So various are the differences of degree and combination in the temperaments, that their divisions and orders may be multiplied almost without end. We shall content ourselves with the four orders commonly received. The sanguineous—most readily, but slightly affected: The choleric—excited readily and violently. The melancholic—excited slowly, but more permanently. And the phlegmatic—excited with difficulty.

This division, although built by Galen on an absurd foundation, borrowed from an imaginary depravation of

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* To the numerous arguments by which the moderns have overthrown the doctrine of the ancients, and proved that the temperament depends on the living solids, rather than on the nature of the blood, I may add the celebrated example of the Hungarian sister twins, who, at the beginning of the last century, were born united at the lower part of the back, and attained their twenty-second year in this state. They were, as is well known, of very different temperaments; although dissection discovered, that their sanguiferous systems anastomosed so considerably, that the blood of both must have been the same.

the elements of the blood, if made to stand alone, appears natural and intelligible.

80. The predisposing and occasional causes of the diversity of temperaments are very numerous; v. c. hereditary tendency, habit of body, climate, diet, religion, mode of life, and luxury.

81. Besides the variety of temperaments, circumstances peculiar to every individual influence the number, as well as the energy and vigour of the functions. In regard to age, the health of a new-born infant is different from that of an adult; in regard to sex, it differs in a marriageable virgin and an old woman past child-bearing; during menstruation and suckling; in regard to mode of life, it is different in the barbarous tribes of North America, and the effeminate Sybarites.

Moreover, in every person, custom has an extraordinary influence over certain functions, v. c. sleep, diet; and has therefore acquired the name of second nature.

82. The more functions flourish simultaneously in the body, the more considerable is its life; and vice versâ. Hence life is greatest, when the functions have attained their highest perfection in adult age; and least, when the functions, although very perfect, are fewer and more sluggish, v. c. in the newly conceived embryo; life is also less vigorous during sleep than during the opposite state.

83. The functions have been long divided by physiologists into four classes. This division, although not unexceptionable, nor exactly conformable to nature, may assist the memory.

The first class comprehends the *vital* functions, so termed, because their uninterrupted performance is necessary to life. Such are the circulation and respiration.

The second comprehends the *animal* functions, by which animals are chiefly distinguished from vegetables. Such is the connexion of the mind with the body, especially sense and muscular motion.

The third is the *natural*, by means of which the body is nourished.

The fourth, the *genital*, intended for the propagation of the species.

We shall now examine each of these separately, beginning with the vital.

SECT. VII.

OF THE MOTION OF THE BLOOD.

84. THE blood, to whose great and multifarious importance in the system we have slightly alluded, is distributed, with a few exceptions, (5) into the most internal and extreme recesses. This is proved, by the minute injection of the vessels; and by the well known fact, of blood issuing from almost every part, on the slightest scratch.

85. This purple fluid does not, like an Euripus, ebb and flow in the same parts, but flows in the course of a circle: so that being propelled from the heart into the arteries, it is distributed throughout the body, and returns again to the heart through the veins*.

86. We shall, therefore, say something at present of the vessels which contain the blood; and afterwards, of the powers by which they propel and receive it.

87. The vessels which receive the blood from the heart, and distribute it throughout the body, are termed *arteries*. These are upon the whole less capacious than the veins;

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* Among warm-blood animals, the egg, at the fourth and fifth day of incubation especially, if placed under a simple microscope, such as the Lyonetian, is most proper to demonstrate the circulation.

Among frogs, the most proper is the equuleus of Lieberkühn, described in the Mem. de l'Acad. de Berlin, 1745.

but in adult and advanced age especially, of a texture far more solid and compact, very elastic and strong.

88. The arteries consist of three coats:

I. The exterior, called, by Haller, the *tunica cellulosa propria*; by others, the nervous, cartilaginous, tendinous, &c. It is composed of condensed cellular membrane, externally more lax, internally more and more compact: blood vessels are seen creeping upon it: it gives tone and elasticity to the arteries.

II. The middle coat consists of transverse fibres, lunated and falciform, and of a fleshy nature: hence this has the name of muscular coat, and appears to be the chief seat of the vital powers of the arteries.

III. The inner coat lining the cavity of the arteries is highly polished and smooth. This is much more distinct in the trunks and larger branches than in the smaller vessels.

89. Every artery originates either from the pulmonary artery (the vena arteriosa of the ancients), which proceeds from the anterior ventricle of the heart, and goes to the lungs; or from the aorta, which proceeds from the posterior ventricle, and is distributed throughout the rest of the system. These trunks divide into branches, and these again into twigs.

90. According to the commonly received opinion, the united capacity of the branches is greater than that of the trunk from which they arise. But I fear that this is too general an assertion; and that the measure of the diameter has been improperly confounded with that of the area. I myself have never been able to verify it, although my experiments have been frequently repeated, and made not on vessels injected with wax, but on the undisturbed vessels of recent subjects—on the innominata, and its two

branches—the right carotid and subclavian; on the brachial, and the radial and ulnar.

The inconstancy of the proportion between the capacity of the branches and trunks is clearly shewn, by the various size of the vessels in different circumstances, v. c. by the relative capacity of the inferior thyroid artery in the infant and the adult; of the epigastric artery, and also of the uterine vessels in a virgin, and a woman far advanced in pregnancy; of the omental vessels during the repletion or vacuity of the stomach*.

91. The arteries, after innumerable divisions and important anastomoses, connecting different branches, terminate at length in the beginning of the veins. By this means, the blood is conveyed back again to the heart. The distinction between artery and vein at the point of union, is lost.

In the present state of our knowledge, the umbilical vessels are to be regarded as the only exception to the termination of arteries in veins. We shall shew that they are connected with the uterine vessels, by the intervention of a spongy substance, called parenchyma.

92. Another description of vessels arise universally from the arteries, and are called colourless, from not containing pure blood, either on account of their minuteness or their specific irritability, which causes them to reject that fluid. These are the nutrient and secretory vessels, of which hereafter.

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* This is remarkably observable in the adult stag, by comparing the area of the external carotid and its branches, during the spring, before the horns have attained their full growth, but are still covered with their downy integuments, with such as it is after this covering has fallen off.

93. The blood conveyed from the heart by the arteries, is carried back by the veins.

These are very different in function and structure from the arteries, excepting however the minutest of both systems, which are undistinguishable.

94. The veins, excepting in the lungs, are upon the whole more capacious than the arteries; are more ramified; much more irregular in their course and division; in adult age, softer and more elastic; but still very firm and expansive.

95. Their coats are so much thinner, that the blood appears through them. They are likewise less in number, being solely a cellular external, somewhat resembling the nerves of the arteries; and a polished internal, also nearly agreeing with that of the arteries.

The muscular coat exists in the largest trunks only.

96. The interior coat forms, in most veins of more than a line in diameter, very beautiful valves, of easy play, resembling bags, generally single, frequently double, and sometimes treble; so placed, that the fundus lies towards the origin of the vein, the limbus towards the heart.

These valves are not found in some parts; not in the brain, heart, lungs, secundaries, nor in the system of the vena portæ.

97. The twigs, or, more properly, the radicles of the veins, unite into branches, and these again into six principal trunks; viz. into the two cavæ, superior and inferior: and the four trunks of the pulmonary vein (the arteria venosa of the ancients).

The vena portæ is peculiar in this, that, having entered into the liver, it ramifies like an artery, and its extreme twigs pass into the radicles of the inferior cava, thus coalescing into a trunk.

98. That the blood may be properly distributed and circulated through the arteries and veins, nature has provided the heart, in which the main trunks of all the blood vessels unite, and which is the grand agent and mover of the whole system,—supporting the chief of the vital functions, with a constant and truly wonderful power, from the second or third week after conception, to the last moment of existence.

99. The heart alternately receives and propels the blood. Receiving it from the body by means of the superior and inferior vena cava, and from its own substance through the common valvular orifice of the coronary veins, it conveys that fluid into the anterior sinus and auricle; thence into the corresponding ventricle, which, as well as the auricle, communicates with both orders of its own vessels, by the openings of Thebesius.

100. From this anterior, or, in reference to the heart of some animals, right ventricle, the blood is impelled through the pulmonary artery into the lungs: returning from which, it enters the four pulmonary veins, and proceeds into their common sinus, the left, or, as it is now more properly termed, the posterior auricle.

101. It flows next into the corresponding ventricle; and then passing into the aorta, is distributed through the general arterial system, and the coronary vessels of the heart.

102. Having proceeded from the extreme twigs of the general arterial system into the radicles of the veins, and from the coronary arteries into the coronary veins, it finally is poured into the two venæ cavæ, and then again pursues the same circular course.

103. The regularity of this circular and successive motion through the cavities of the heart is secured, and any

retrograde motion prevented, by the valves which are placed at the principal openings: viz. at the openings of the auricles into the ventricles, and of the ventricles into the pulmonary artery and aorta.

104. Thus the ring, or venous tendon, which forms the limit of the anterior auricle and ventricle, descending into the latter cavity, becomes three tendinous valves. These were formerly said to have three apices, and were therefore called trigochline, or tricuspidal: they adhere to the fleshy pillars, or, in common language, the papillary muscles.

105. In a similar manner, the limits of the posterior auricle and ventricle are defined by a ring of the same kind, constituting two valves, which, from their form, have obtained the appellation of *mitral*.

106. At the opening of the pulmonary artery and aorta are found the triple *semilunar* or sigmoid valves, fleshy and elegant, but of less circumference than the mitral.

107. It is obvious, that these valves must prevent the retrocession of the blood into the cavæ. They readily permit the blood to pass on, but are expanded, like a sail, against it, by any attempt at retrograde movement.

108. The texture of the heart is peculiar: fleshy, indeed, but very dense and compact, far different from common muscularity. It is composed of fasciculi of fibres, more or less oblique, here and there singularly branching out, curiously contorted and vorticose in their direction, lying upon each other in strata, closely interwoven between the cavities, and bound by four cartilaginous bands to the basis of the ventricles, which are thus supported and distinguished in their texture from the fibres of the auricles.

109. These fleshy fibres are supplied with very soft

nerves, and an immense number of blood vessels, which arise from the coronary arteries, and are so infinitely ramified, that Ruysch described the whole structure of the heart as composed of them.

110. The heart is loosely contained in the *pericardium*. This is a membranous sac, arising from the mediastinum, of the same figure as the heart, very firm, and moistened by an exhalation from the arteries of the heart. Its importance is evinced by its existence being, in red blooded animals, as general as that of the heart; and by only two instances being recorded of its absence in the human subject.

111. By this structure, the heart is adapted for perpetual and equable motions, which are an alternate systole and diastole, or contraction and relaxation of the auricles and ventricles in succession.

112. Thus, as often as the auricles contract to impel the blood of the venæ cavæ and pulmonary veins into the ventricles, these are at the same moment relaxed, to receive the blood: immediately afterwards, when the distended ventricles are contracting to impel the blood into the two great arteries, the auricles relax, and receive the fresh venous supply.

113. The systole of the ventricles, upon which is spent one third of the time of the whole action of the heart, is performed in such a way, that their external portion is drawn towards their septum, and the apex of the heart towards the base. This at first seems disproved, by the circumstance of the apex striking against the left nipple, and consequently appearing elongated: a circumstance, however, to be attributed to the double impetus of the lood flowing into the auricles, and expelled from the ven-

tricles, by which the heart must be driven against that part of the ribs (A).

114. The impulse imparted by the heart to the blood, is communicated to the arteries, so that every systole of the heart is remarkably evident in those arteries which can be explored by the fingers, and exceed $\frac{1}{6}$ of an inch in diameter, and in those also whose pulsation can be otherwise discovered, as in the eye and ear. The effect upon the arteries is called their diastole, and is correspondent and synchronous with the systole of the heart.

115. The quickness of the heart's pulsations during health, varies indefinitely; chiefly from age, but also from other conditions, which at all ages form the peculiar health of an individual; so that we can lay down no rule on this point. I may, however, be permitted to mention the varieties which I have found in our climate* at different ages; beginning with the new-born infant, in which, while placidly sleeping, it is about 140 in a minute.

Towards the end of the first year, about	124
- - - - - - - - second - - -	110
- - - - - - - - third and fourth	96
When the first teeth begin to drop out -	86
At puberty - - - - - - - - - -	80
At manhood - - - - - - - - - -	75
At sixty, about - - - - - - - - -	60

In those more advanced, I have scarcely twice found it alike.

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* My observations differ but little from those made by Heberden in England. Med. Trans. ii. p. 21. et seq.

116. The pulse is, ceteris paribus, more frequent in women than in men, and in short than in tall persons. A more constant fact, however, is its greater slowness in cold climates. Its greater frequency after meals and coition, during continued watchfulness, exercise, or mental excitement, is universally known.

117. The heart rather than the arteries is to be regarded as the source of these varieties.

Its action continues in this manner till death, and then all its parts do not, at once, cease to act; but the right portion, for a short period, survives the left*.

For since the collapsed state of the lungs impedes the course of the blood from the right side, and since the veins must be turgid with the blood just driven into them from the arteries, it cannot but happen that this blood, driving against the right auricle, must excite it to resistance for some time after the death of the left portion of the heart.

118. This congestion on the right side of the heart, affords an explanation of the small quantity of blood found in the large branches of the aorta. Weiss, and after him Sabatier, ascribes to this cause likewise the comparatively larger size of the right auricle and ventricle in the adult dead subject especially.

119. The motion of the blood is performed by these two orders of vessels, in conjunction with the heart. Its

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* Sometimes, though rarely, it happens, that the right portion of the heart oppressed with too much blood, becomes, contrary to what usually takes place, paralyzed bef re the left. This I have more than once observed on opening living mammalia, particularly rabbits.

celerity in health cannot be determined: for it varies not only in different persons, but in different parts of the same person. Generally, the blood moves more slowly in the veins than in the arteries, and in the small vessels than in the large trunks. But these differences have been overrated by physiologists.

The mean velocity of the blood flowing into the aorta is usually estimated at eight inches for each pulsation, or at fifty feet in a minute.

120. Some have affirmed that the globules of the cruor move more in the axis of the vessels, and with greater rapidity, than the other constituents of the blood. I know not whether this rests on any satisfactory experiment, or whether upon an improper application of the laws of hydraulics; improper, because it is absurd to refer the motion of the blood through living canals, to the mere mechanical laws of water moving in an hydraulic machine. I have never observed this peculiarity of the globules. My persuasion is more certain that the globules pass on with the other constituents of the blood, and are not rotated around their own axis,—that besides the progressive, there is no intestine motion in the blood; although indeed there can be no doubt, that the elements of this fluid are occasionally divided, where it is variously impelled according to the different direction, division, and anastomoses of the vessels.

121. The powers of the sanguiferous system are now to be examined: first, those of the heart, by far the greatest of all; afterwards, those which are only subsidiary, though indeed highly useful.

122. That the powers of the heart cannot be accurately calculated, is clear, upon reflecting that neither the vo-

lume of the blood projected at each pulsation, nor the celerity, nor distance of its projection, much less the obstacles to the powers of the heart, can be accurately determined.

123. A rough calculation may be made by comparing every probable conjecture; v. c. if the mean bulk of the blood is considered as 10 pounds, or 120 ounces; the pulsations 75 in a minute, or 4500 in an hour; and the quantity of blood expelled from the left ventricle on each contraction, as two ounces; it follows that all the blood must pass through the heart 75 times in a ~~minute~~ hour. The impetus of the blood passing from the heart, may be conceived by the violence and altitude of the stream projected from a wounded artery, large and near the heart. I have seen the blood driven to the distance of at least five feet from the carotid of an adult and robust man*.

124. This wonderful strength of the heart is universally allowed to depend on its irritability, in which it

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* The experiments of Hales, in which the blood was received into very long glass tubes, fixed to the arteries of living animals, and measured with respect to the length of its projection, are indeed elegant, like every thing done by this philosopher, who was by nature calculated for such disquisitions. But if the force of the heart is to be estimated in this way, we must take into account the pressure of the column of blood contained in the tube, and gravitating upon the left ventricle. The result of Hales' calculations was, that the blood being projected from the human carotid seven feet and a half, the surface of the left ventricle being fifteen square inches, a column of blood, weighing 51lb. 5oz. was incumbent upon the ventricle, and overcome by its systole.

surpasses, especially in continuance*, every other muscular part.

That the parietes of the cavities are excited to contraction by the stimulus of the blood, is proved in the experiment of Haller, who lengthened at pleasure the motion of either side of the heart, by affording it the stimulus of the blood, for a longer period than the other (B).

125. Since a supply of nerves and blood is requisite to the action of the voluntary muscles, it has been enquired whether they are requisite to the heart also.

The great influence of the nerves over the heart, is demonstrated by the size of the cardiac nerves, and by the great sympathy between the heart and most functions, however different. A convincing proof of this, is the momentary sympathy of the heart during health with the passions, and with the primæ viæ under various disorders. But the great importance of the blood to the irritability of the heart, is evident by the great abundance of vessels in its muscular substance.

Nevertheless it is very probable, that the importance of the nerves in this respect is greater in the voluntary muscles, and of the blood in the heart.

126. Besides these powers of the heart, there is another, which is mechanical, dependent on structure, greatly contributing, in all probability, to sustain the circulation. For when the blood is expelled from the

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* Thus, to say nothing of the phenomena so frequently observed in the cold blooded amphibia and fishes, I lately found the heart of the chick, beat for twelve hours, in an egg on the fourth day of incubation.

contracted cavities, a vacuum takes place, into which, according to the common laws of derivation, the neighbouring blood must rush, being prevented, by means of the valves, from regurgitating.

127. We must now inquire, what powers are possessed by other organs in assisting the circulation. Their existence and capability of assisting, or even in some cases of compensating the action of the heart, are proved by several arguments: v. c. the blood moves in some parts to which the influence of the heart cannot reach,—in the vena portæ and placenta; not to mention instances of the absence of the heart.

128. The principal of these powers is the function of the arteries, not easy indeed to be clearly understood and demonstrated. 1. They have a muscular coat (C). 2. They are irritable, as is proved by repeated experiments. 3. The size of the soft nerves arising from the sympathetic, and surrounding the arteries, particularly in the lower part of the abdomen, argues the importance of these vessels in assisting the motion of the blood.

129. The arteries pulsate, and indeed violently, so that if, v. c. we place one leg over the other knee, we find not only that it, but even a much greater weight, may be raised by the pulsation of the popliteal. Hence an alternate systole and diastole, corresponding with those of the heart, has long been assigned to them. But this, although believed on the evidence of sense, is open to much question: it may be asked, especially, whether this pulsation is referable to the power of the artery, or only to the impulse given by the heart to the blood propelled into the aorta.

130. And indeed after all, it appears, that the diastole of an artery is owing to the blood,—to a lateral distension

given by the impetus of the blood, so that the coats are expanded; and the vessel, by its elasticity, the next moment reacquires its natural thickness. To the same impulse may be ascribed the lateral motion of the axis, observable in the larger arteries, if serpentine and lying in loose cellular substance.

The genuine systole, produced by a constriction of their usual thickness, scarcely occurs, probably, while the heart acts with sufficient vigor; but when they are unusually stimulated, or if the action of the heart fails or is impeded by severe disease, then indeed the arteries may supply its place, and propel the blood by their own vital energy.

131. Since Whytt and other illustrious physiologists have been convinced that the influence of the heart could not reach the extreme arteries and the origins of the veins, they have ascribed the progression of the blood in those vessels to a kind of oscillation, and have happily employed this to demonstrate the nature of inflammation. Many kinds of phenomena, both physiological, as those regarding animal heat, and pathological, as those observed in spasms, and particularly in fevers, favor the supposition of this oscillatory faculty, though it is not demonstrable to the eye.

132. It remains now to inquire into the aid given to the returning blood by the veins, not alluding at all to their radicles. We should conclude at first sight that they have less active power* than the rest of the san-

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* What is commonly, but improperly, called the venous pulsation, observable on opening living animals, and in some morbid affections, does not correspond with the action of the heart, but

guiferous system, and that the return of their purple blood to the heart, is chiefly ascribable to the impetus a tergo of the arterial blood, and their valvular structure, which prevents any reflux. The efficacy of the valves in this point of view, is shewn by those distensions and infarctions of the veins in the lower part of the abdomen, which are found destitute of valves.

The existence of vital powers in the venous trunks, is probable, from the example of the liver and placenta (127), and from experiments instituted on living animals. We formerly mentioned the muscular appearance in the extreme veins near the heart (95).

133. These are the chief powers which move the blood, and depend upon the structure and vitality of the sanguiferous system: I say nothing of the effect of gravity, attraction, and other powers, common to all matter. The more remote assistance derived after birth from peculiar functions, v. c. respiration and muscular motion, will be manifest in our account of those functions.

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with respiration; since if an exspiration is unusually deep and lengthened, and the reflux of the blood to the lungs thus impeded, the jugular vein swells as far as the brain, the subclavian as far as the basilic, and the inferior cava as far as the crural.

NOTES.

(A) Dr. W. Hunter first accounted for this in the year 1746. Vide J. Hunter on the Blood, &c. page 146. Note. " The systole and diastole of the heart, simply, could not produce such an effect; nor could it have been produced, if it had thrown the blood into a straight tube, in the direction of the axis of the left ventricle, as is the case with fish and some other classes of animals; but by its throwing the blood into a curved tube, viz. the aorta, that artery, at its curve, endeavours to throw itself into a straight line, to increase its capacity; but the aorta being the fixed point against the back, and the heart in some degree loose or pendulous, the influence of its own action is thrown upon itself, and it is tilted forwards against the inside of the chest."

(B) The heart, however, in experiments made on animals, has been found to continue its contractions, when destitute of blood.

(C) While most physiologists allow the muscularity of the capillaries, many disbelieve its existence in this coat. The objections of Bichat, are the absence of irritability on the application of stimuli; its much greater resistance to an extending force than that of muscular parts; lastly, the difference of the changes which it and the muscles undergo, both spontaneously and by the action of other substances. Anatomie Generale, t. ii.—Berzelius has multiplied the proofs of the latter description, and concludes that, " as the arterial fibre neither has the structure of a muscle, nor its chemical properties and composition, it cannot be a muscle, nor perform the functions of a muscle, which is besides sufficiently evident from its elasticity. This elasticity, however, compensates fully the muscular power." Animal Chemistry, p. 25.

SECT. VIII.

OF RESPIRATION AND ITS PRINCIPAL USE.

134. THE *lungs*, closely connected with the heart, both by proximity and by relation of function, are two viscera, large after birth, so light as to swim in water, and composed of a spongy, and, as it were, spumous, but pretty tenacious, parenchyma.

135. They fill each cavity of the chest, are contiguous to the sacs of the pleuræ, to which, as well as to the other contents of the thorax, they model and apply themselves (A).

136. They, in a manner, hang from the wind-pipe, usually called the aspera arteria, which, besides its interior coat always smeared with mucus, and the subjacent very sensible nervous coat, consists of another which is muscular, surrounding the latter, and divided, except posteriorly, by an irregular number of cartilaginous falciform arches.

137. The aspera arteria, having entered the thorax, is bifurcated into the two bronchiæ, and these, the more deeply they penetrate into the lobes of the lungs, are more and more ramified, losing both their cartilaginous rings and muscular coat, until their extreme divisions terminate in those cells which form the chief part of the lungs, and ultimately receive and emit the air we breathe.

138. The shape and magnitude* of the air cells are various, the former is generally polyedrical; the latter, in regard to surface, scarcely to be defined†: though, indeed, the capacity of the lungs of an adult, during a strong inspiration, is about 120 cubic inches. The immense size to which the lungs may be inflated, when the chest has been opened, has no relation to our present subject.

139. The cells are invested and connected by the common but delicate mucous web,—the general vinculum of the body. The texture of each must be carefully distinguished. In healthy and recent lungs, the cells are so distinct from the mucous web, that they are distended by air cautiously inflated into the bronchiæ, while the latter does not admit a single portion. If air is forcibly thrown in, the air cells are ruptured, and both parts distended.

140. The mucous web in the lungs is supplied with innumerable blood vessels,—divisions of the pulmonary artery and four pulmonary veins; the branches of which accompany the ramifications of the bronchiæ, and, after repeated division, form at length a most delicate and immense collection of reticulated anastomoses. This extraordinary net-work, penetrating the mucous web on every side, closely surrounds the air cells, so that the prodigious quantity of blood, existing in the pulmonary vessels, is separated from the contact of the air, by very

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* Keil indulging his iatro mathematical genius, assigned more than 1744,000,000 to each lung.

† Lieberkuhn, with equal exaggeration, made the surface of the cells equal to 1500 square feet.

fine membranes only, which Hales estimated as scarcely $\frac{1}{1000}$ part of an inch in thickness.

141. As each ramification of the bronchiæ possesses a peculiar bunch or lobule of air cells, so again each of these possesses a peculiar system of blood vessels, the twigs of which anastomose in the net-work with one another, but not at all with the blood-vessels of the other lobules, as is proved by microscopic observations on living frogs and serpents, by minute injections, and by the phenomena of vomicæ and other local diseases of the lungs.

142. The common membrane investing the lungs is the chief seat of a remarkable net-work of lymphatic vessels which run to numerous lymphatic or conglobate glands, to be carefully distinguished from a neighbouring order of glands, called bronchial, supplied with an excretory duct, and of the conglomerate kind.

143. The thorax, which contains the lungs, has an osseous and cartilaginous base, somewhat resembling a bee-hive, generally very firm and stable, but in every part more or less moveable for the purpose of respiration.

This holds good chiefly with the six pairs of true ribs, below the first pair, each of which is more moveable than the one above, and in proportion to the greater length both of their own bodies and of the cartilaginous appendices, which are united by a kind of amphiarthrosis to the margin of the sternum on each side.

144. Between the edges of the ribs, lie two strata of intercostal muscles, differing in the direction of their fibres, but conspiring to produce the same motion.

At the base of the thorax, the diaphragm is subtended in the form of an arch. It is a considerable muscle, and, in the words of Haller, next in importance to the heart. Its utility in respirarion was long since shewn, by the excellent experiments of Galen upon living animals, to depend on the phrenic nerve.

Its antagonists are the abdominal muscles, especially the two oblique and the transverse.

145. The thorax thus constituted, is, after birth, dilated by inspiration, and subsequently reduced to smaller capacity by exspiration.

During the former act, the thorax is enlarged laterally and inferiorly, so that the bodies of the six ribs mentioned above (143) are elevated, and their inferior margin drawn outwards. The arch of the diaphragm is at the same time depressed and flattened.

I have never observed the inferior extremity of the sternum, in tranquil respiration, to be thrust forwards, as some have asserted.

146. This alternate motion of the chest continues during health and freedom from restraint, from the hour of birth till death. The object of this motion is, that the lungs may be expanded to admit the air, and contracted to expel it, in perpetual alternation. This alternation in an adult at rest, occurs about 14 times in a minute, once to about five pulsations of the heart.

147. For man, in common with all warm-blooded animals, cannot long retain the inspired air, but is compelled to discharge it, and take in a fresh supply of this pabulum of life, as it always has been denominated. Common observation teaches, that however pure may be the air entering the lungs, it instantly undergoes re-

markable changes, by which it is contaminated and rendered unfit for another inspiration, unless it is renewed*.

148. It may be asked what are the changes which the air experiences during inspiration, and which consist not in the loss of elasticity, as was formally supposed, but in the decomposition of its elements. For the atmospheric air we breathe, is a singular mixture of constituents, differing in nature from each other; and, not to mention heterogeneous matters, such as odorous effluvia, various exhalations, and innumerable others, is always impregnated with aqueous vapor, electric and magnetic matter, and generally with carbonic acid gas; and is itself composed of unequal parts of two aeriform fluids, viz. 79 of azotic gas, and 21 of oxygen gas in 100.

149. In the first place we know for certain, that, at every inspiration, (the fulness of which varies infinitely in men of the same age, breathing placidly,) besides the quantity of azotic gas being somewhat diminished, the oxygen gas is in great measure converted into carbonic acid gas, or fixed air; so that the air of expiration, if collected, instantly extinguishes flame and live coals, precipitates lime from lime water, and is specifically heavier than atmospheric air, and rendered unfit for respiration†: it also contains much aqueous vapor, which

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* The antiquity of the notion that air is the pabulum vitæ, is seen in the book *de Flatibus*, usually ascribed to Hippocrates. The author regards the aliment as threefold, victuals, drink, and air: but the latter he calls vital, because we cannot dispense with a perpetual supply of it, without danger to life.

† To discover how frequently an animal could breathe the same portion of air, I took three dogs equal in size and strength; and to

is condensed in the form of halitus, by a temperature of 60° of Fahr.

150. It is therefore probable, that, during inspiration, the oxygenous portion is set at liberty, and, being united with the arterial blood, is conveyed throughout the system; while the carbon and hydrogen are brought back with the venous blood to the right side of the heart, and thrown off like smoke, according to the ancients, in the lungs (B).

The more florid colour of the arterial blood, the darker of the venous, and the analogous appearance of the blood, if exposed to the gases in question, correspond admirably with this theory (C). Some difficulties, indeed, remain to be solved, v. c. how the carbon can be united in the lungs with the oxygen, so as to fly off in the form of carbonic acid gas.

151. This perpetual change of elements occurring in respiration after birth, we shall show to be very differently accomplished in the fœtus, viz. by means of the connexion of the gravid uterus with the placenta. But when the child is born, and capable of volition, a congestion

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the trachea of the first, by means of a tube, I tied a bladder, containing about 20 cubic inches, of oxygen gas. He died in 14 minutes.

With the second, the bladder was filled with atmospheric air. He died in 6 minutes.

With the third, I employed the carbonized air expired by the second dog. He died in 4 minutes.

Upon afterwards examining the air of the bladder, it gave the common signs of carbonic acid gas. The instruments which I employed are described and illustrated by a plate in the Medic. Biblioth. vol. 1. p. 174. et seq. tab. 1.

takes place in the aorta, from the obstruction in the umbilical arteries: the danger of suffocation from the cessation of those changes of the blood, in regard to oxygen and carbon, hitherto produced in the uterine placenta; the novel impression of that element, into which the child, hitherto an aquatic being, is conveyed; the cooler temperature to which it is now exposed, and the many new stimuli which are now applied, seem to induce new motions in the body, especially the dilatation of the chest and the first inspiration.

The lungs having for the first time inspired, open a new channel to the blood, so that, being obstructed in the umbilical arteries, it is derived to the chest.

Since the inspired air becomes hurtful and unpleasant to the lungs, by the decomposition it experiences, we would ascribe to the most simple corrective powers of nature, the subsequent motion by which the poisonous mephitis, as it may be called, is expelled and changed for a fresh supply (D).

The consideration of all these circumstances, especially if the importance of respiration, demonstrated by the well-known experiment of Hooke, be remembered, will, in my opinion, explain the celebrated problem of Harvey, better than most other attempts made by physiologists (E).

NOTES.

(A) A CORRECT notion cannot be formed from this description. The pleura forms two closed sacs, one of which is interposed between each lung and the parietes of the chest: one portion of the sac adhering to the latter, and the other portion to the former; but the internal surfaces of both portions are

always in contact; because, if the parietes of the thorax expand and draw with them the external portion, the lungs expand with air, and force out the internal in the same degree.

(B) Chemists have now proved that no nitrogen is absorbed in respiration, and that the oxygen gas which disappears is exactly sufficient to form the carbonic acid gas which is produced, so that neither of them enter into the blood. The only chemical change of the blood, therefore, during respiration, is the separation of carbon.

(C) Blood taken out of the body absorbs oxygen abundantly; serum, destitute of colouring matter, produces no change in the air, till putrefaction commences, according to Berzelius.

(D) Respiration has been considered as a mixed function, intermediate between the voluntary and involuntary. It clearly belongs to the voluntary. When the blood accumulates in the lungs, the uneasy sensation which we feel, prompts us instinctively to inspire for the purpose of removing it; expiration follows from relaxation, invariably consequent to muscular contraction, occurring in the muscles which were contracted during inspiration, and allowing effect both to their elastic and muscular antagonists. But it may be urged, that we cannot avoid inspiring. Nor are we more able to avoid contracting any voluntary muscle, if, by so doing, we escape from pain or uneasiness. If some persons, from their firm resolution, have stood motionless while burning, others have been known to suspend their breathing till they fell down lifeless.

(E) The experiment consisted in laying the lungs completely bare, and supporting life by continuing respiration artificially. Hooke varied it by pricking the surface of the lungs, and forcing a continued stream of air through them.

The following are the words of Harvey: "It would appear that the use of exspiration is to ventilate and purify the blood, by separating from it these noxious and fuliginous vapors."

SECT. IX.

OF THE VOICE AND SPEECH.

152. I HAVE described the chief use of respiration. I shall hereafter mention how far it contributes to the conversion of the chyle into blood, and to the support of almost the whole class of natural functions. Its other uses are at present to be considered.

And first, respecting the voice. This takes place after birth; and proceeds from the lungs, as was observed long ago by Aristotle, who called those animals only vocal, which breathed by means of lungs. The voice is, properly speaking, a sound, formed, by means of expiration, in the *larynx*, which is a most beautifully constructed organ, fixed upon the top of the windpipe, like a capital upon a pillar.

153. The larynx is composed of various cartilages, which being united together iu the form, as it were, of a little box, and supplied with a considerable and wonderful apparatus of muscles, may be moved altogether, or separately, according to the variations of the voice.

154. The part of the larynx most concerned in producing the voice, is the *glottis*, or narrow opening of the windpipe, having the epiglottis suspended, and, in a manner, fixed upon it. It is clearly ascertained, that the air, expired from the lungs, and striking properly upon the margins of the glottis becomes sonorous.

155. But it has been disputed what changes the glottis undergoes in modulating the voice. Whether it is alternately widened and constricted, as Galen and Dodart supposed, or whether, according to Ferrein, the variations of voice are effected rather by the tension and relaxation of its ligaments. The latter, consistently with his opinion, compared the larynx to a violin; the former, more consistently with nature, to a flute*.

Every thing considered, we must conclude, that the larynx experiences both kinds of changes; since the grave and acute modulation of the voice must depend very much upon the alterations produced in the larynx by the ligaments, especially by the inferior thyreo-arytenoids, (the vocal chords of Ferrein,) and the corresponding modification of the sinuses, or ventricles of the larynx.

156. That every degree of motion in the glottis is directed by the muscles of the larynx, is proved by the beautiful experiment of tying or dividing the recurrent nerves, or par vagum, and thus weakening or destroying the voice of the animal (A).

157. Man and singing birds have the power of whistling. In the latter, it is accomplished by a larynx, placed at each extremity of the wind pipe, and divided into two portions. The former, though possessing a single and

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* Kratzenstein viewed the glottis and larynx as a drum, with its head bisected. Tentamen de natura et charactere sonorum litterarum vocalium. Petrop. 1781-4.—I would, in some sense, compare it to an Eolian harp, particularly one of the description found by Labillardiere in Amboyna. Voyage à la recherche de la Perouse, t. i. p. 326.

undivided larynx, has learned, I imagine, to imitate birds, by the coarctation of the lips*.

158. Singing, which is composed of speech and an harmonic modulation of the voice, I conceive peculiar to man, and the chief prerogative of the vocal organs. Whistling is conmate in birds; many of them may easily be taught to pronounce words: and instances have been known of this even in dogs. But it is recorded, that genuine singing has once or twice only, then indeed but indifferently, and with the utmost difficulty, been taught to parrots; while, on the other hand, scarcely a barbarous nation exists, in which singing is not common†.

159. *Speech* is a singular modification of the voice, composed to the formation of the sounds of letters, by the expiration of air through the mouth or nostrils, and in a great measure by the assistance of the tongue, applied and struck against the neighbouring parts, the palate and teeth in particular, and by the diversified action of the lips.

The difference between voice and speech is therefore evident. The former is produced in the larynx, the

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* The larynx, even among the most ferocious people, is capable of imitating the sound of animals.

Nic. Witsen Noord en oost. Tartarye ed. 2. Amst. 1705. vol. i. p. 165, respecting the inhabitants of New Guinea.

Also Ja. Adair in his History of the American Indians, p. 309, respectiug the Chatkah tribe of North America.

† I have in my hands the testimony of most respectable travellers, in regard to the inhabitants of Ethiopia, Greenland, Canada, California, Kamtschatska, &c. and therefore wonder at the assertiou of Rousseau, that singing is not natural to man. Dictionn. de Musique vol. i. p. 170. Genev. 1781—12.

latter by the singular mechanism of the organs above described.

Voice is common both to brutes and man, even immediately after birth; nor is entirely absent in those wretched infants who are born deaf. But speech follows the culture and employment of reason, and is, consequently, like it, the privilege of man in distinction from the rest of animal nature. For brutes, natural instinct is sufficient; but man, destitute of this and other means of supporting his existence independently, enjoys the prerogative of reason and language, and following, by their means, his social destination, is enabled to form, as it were, and manifest his ideas, and communicate his wants to others by the organs of speech.

160. The mechanism of speech and articulation is so intricate, and in a great measure unknown, that even the division of letters, and their distribution into classes, is attended with much difficulty.

The division, however, of Ammann, into vowels, semi-vowels, and consonants, is very natural:

I. He divides the vowels into *simple*, *a*, *e*, *i*, *y*, *o*, *u*, and mixed, *ä*, *ö*, *ü*.

These are of the simplest formation:

The semi-vowels and consonants are articulated by the mechanism of speech.

II. The semi-vowels are *nasal*, *m*, *n*, *ng*, (*n* before *g*, which is nearly related to it,) that is, the labio-nasal *m*; the dente-nasal *n*; and the gutture-nasal *ng*; or oral (lingual) *r*, *l*; that is, *r* with a vibration of the tongue; or *l*, with the tongue less moved.

III. The consonants are distinguished into *hissing* (pronounced in succession) *h*, *g*, *ch*, *s*, *sch*, *f*, *v*, *ph*; that is *h*, formed in the throat, as it were a mere aspiration; *g* and

ch true consonants; *s*, *ch*, produced between the teeth; *f*, *v*, *ph*, formed by the application of the lower lip to the upper front teeth: and *explosive*, (which are, in a manner, exploded, by an expiration, for some time suppressed or interrupted,) that is, *k*, *q*, formed in the throat; *d*, *t*, near the teeth; *p*, *b*, near the lips; and *double* (compound) *x*, *z*.

161. We must just mention certain other modifications of the human voice, some of which, as hiccup and cough, belong more properly to pathology than to physiology, but are very common in the most healthy persons; and others, as weeping and laughing, appear peculiar to the human race.

162. Many of these are closely allied, and frequently even converted into each other; some also are variously modified.

In *laughter* there is a succession of short and abrupt expirations.

Coughing is a quick, violent, and sonorous expiration, following a deep inspiration.

Sneezing, generally the consequence of an irritation of the mucous membrane of the nostrils, is a violent and almost convulsive expiration, preceded by a short and violent inspiration.

Hiccup, on the contrary, is a sonorous, very short, and convulsive inspiration, excited by an unusual irritation of the cardia.

Weeping consists of deep inspirations, quickly alternating with long and sometimes interrupted expirations.

Sighing is a long and deep inspiration, and the subsequent expiration is sometimes accompanied by groaning.

Nearest in relation to sighing is *gaping*, which is produced by a full, slow, and long inspiration, followed by

a similar expiration, the jaws at the same time being drawn asunder; so that the air rushes into the open fauces and the Eustachian tubes. It occurs from the blood passing through the lungs too slowly; v. c. when the pressure of the air is diminished, as upon high mountains. A remarkable feature of gaping is the propensity it excites in others to gape likewise; arising, no doubt, from the recollection of the pleasure it produced.

NOTE.

(A) M. Le Gallois has ascertained that the division of the recurrent nerves frequently proves fatal in animals, and that its effect is to paralyse the arytenoid muscles, thus relaxing the ligaments of the glottis, the aperture of which is therefore diminished. This effect, however, varies with the kind and age of the animal. The danger diminishes as the animal is older; and, after a certain age, little inconvenience follows.

SECT. X.

OF ANIMAL HEAT.

163. MAN, the mammalia, and birds, are distinguished by the natural temperature of their bodies greatly exceeding that of the medium in which they are accustomed to exist. Man is again distinguished from these classes of animals, by possessing a much lower temperature than they; so that in this climate it is about 96° of Fahr. while in them, and especially in birds, it is considerably higher*.

164. This natural temperature in man, is so constant, equable, and perpetual, that variety of constitution causes it to vary but slightly, even in the coldest climate, and under the torrid zone. For the opinion of Boerhaave, that man cannot live in a temperature exceeding his own, has been refuted by the admirable observations of H. Ellis, the celebrated traveller, and formerly the captain

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* The torpid state of some animals, during winter, is of course an exception to this. Most of the functions cease or languish considerably; and the animal heat is reduced nearly to coolness. This circumstance prevents me from acceding to the opinion of J. Hunter, that warm-blooded animals should be considered as retaining their heat under all temperatures. On the blood, p. 15.

of the George, and by the remarkable experiments of many excellent physiologists*. This striking prerogative of man is evinced by his being restricted to no climate, but inhabiting every part of the earth from Hudson's bay, where Mercury freezes, and from Nova Zembla, to the scorching shore of Senegal.

165. The explanation of this circumstance, is equally simple and natural, and founded on the doctrine which makes the lungs the receivers; and the decomposition of the oxygenised portion of the air the source of our heat.

166. For, as the oxygenous gas is decomposed in the air cells of the lungs, in such a way, that its base, which, by its union with latent caloric, was before aëriform, now separates from this caloric, it would appear that, by this decomposition, one portion of the caloric is rendered sensible in the bronchiæ, while the other enters into the blood in a latent form.

167. When the oxygenised blood thus charged with latent heat, circulates through the aortic system, it acquires carbon in the small vessels, and sets free the latent heat it had received; thus our animal heat is principally produced†.

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* The heat of the weather, even in Europe, occasionally exceeds our natural temperature. This was the case on the third of Aug. 1783, at noon, when I was on the Lucern Alps, in company with the excellent Schnyder de Wartensee. The thermometer in the shade stood above 100° Fahr. and when applied to the body, invariably sunk to 97°.

† Hence the constant coldness of those wretched beings who labour under the blue disease, which arises from a mal-conformation of the heart. Sometimes the septa of the heart are imperfect,

168. Its production and regulation, however, appear much influenced by the *secretion* of fluids from the blood, both those which are liquid and destined to solidify by assimilation and nutrition, and those which are permanently elastic.

169. Since these changes are effected by the energy of the *vital powers*, the great influence of these upon our temperature must be easily perceived.

170. Many arguments render it probable, that the action of the minute vessels, and the conversion of oxygenised into carbonised blood, are dependent upon the varied excitement or depression of the vital principle.

For the remarkable phenomena of the stability of our temperature, (proved by the thermometer, and not by the sense of touch, which may be fallacious,)—that it is neither increased by the heat of summer, nor diminished by the cold of winter, but found sometimes even to increase on immersion in cold water, demonstrate that the action of the minute vessels varies according to the temperature of the medium in which we are placed: so that, when exposed to a low temperature (by which their tone is augmented) more oxygen is changed for carbon, and more heat evolved; while in a high temperature this action is diminished, and less heat evolved.

171. The *corium* or *cutis*, and the internal surface of the *alimentary canal*, eminently contribute, if I am not much mistaken, to regulate our temperature. For

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sometimes the aorta arises with the pulmonary artery, from the right ventricle, as in the tortoise. In such instances, the chemical changes cannot take place in the lungs.

both these organs are supplied with an immense number of blood-vessels, analogous in this respect to the lungs, and so intimately connected with the lungs by means of sympathy, as in some degree to perform a part and occasionally the whole of their functions in their room. This is exemplified in adults labouring under nearly total consumption, or other violent affections of the lungs, and nevertheless existing for a length of time, almost without respiration.

172. This opinion respecting the action of the cutaneous vessels in exciting, moderating, or almost extinguishing our heat, receives much support from the physiological and pathological fact, of *some parts* being frequently of a higher or lower temperature than the rest of the system.

Thus we must attribute the coldness of the dog's nose to the action of its own vessels, being modified differently from that of the rest; so also, the burning of the cheeks and palms of the hands in hectic fever, not to mention other phenomena of the same description, v. c. the heat of the genitals during the venereal œstrum; and the irresistible coldness of the feet in certain diseases.

173. The alimentary canal is the only internal part, besides the lungs, exposed to the contact of the atmosphere. There is scarcely occasion to prove that it is so exposed, and that we swallow a considerable quantity of air.

The air, when swallowed, is decomposed in the stomach and intestines, so that, during health, it soon loses its elastic form: not, however, when the capillaries of the canal are debilitated, or when it exists in too great quantity.

The extraordinary congeries of blood-vessels in the intestines, on their internal surface, which is usually believed equal to the external surface of the body, agrees very well with this idea.

NOTE.

(A) No phenomenon in living bodies is more remarkable than their peculiar temperature, and no one was of more difficult solution before the progress of modern chemistry. If two different bodies are placed in a temperature, higher or lower than their own, for a certain length of time, they will, at the end of the period, be found not of the same, but of different, temperatures. That which has the higher temperature, is said to have a smaller capacity for caloric; that which has the lower, a greater capacity. To raise the former to a given temperature, therefore, requires less heat than to raise the latter to the same degree.

The temperature of solids is more easily affected by a given quantity of heat, than that of fluids: or in other words, solids have a smaller capacity for caloric, than fluids, and fluids than aeriform bodies. If, therefore, a solid becomes fluid, or a fluid aeriform, it absorbs a great quantity of heat, though its temperature remain precisely the same. And the converse holds equally good, if an aeriform substance becomes liquid, or a liquid solid, the heat which it before contained is now (from the diminished capacity of the body) much more than sufficient for the temperature which before existed, and the temperature of the body accordingly rises.

In respiration, the dark blood of the pulmonary artery parts with a portion of its carbon, and acquires a florid hue. This

carbon unites with the oxygen of the inspired air, and forms carbonic acid, which is expired with the other constituent of the atmosphere,—nitrogen or azote,—which appears to have experienced no change from inspiration.

Dr. Crawford rendered it probable, by his experiments, that the arterial blood has a larger capacity for caloric than the venous; and common air, than carbonic acid gas. When, therefore, the carbon of the venous blood unites with the oxygen of the air, and forms carbonic acid, the less capacity of this than common air for caloric, must cause an increase of temperature, but the blood having changed from venous to arterial, has acquired a greater capacity than before, and absorbs the heat given out by the carbonic acid. The blood, of course, does not become warmer, because the heat is not more than sufficient to render its temperature equal to what it was previously; and indeed it is not quite sufficient for this, for the arterial blood of the pulmonary veins is generally two degrees lower than that of the pulmonary artery.

The body in this way acquires a fund of heat, and yet the lungs, in which it is acquired, do not experience any elevation of temperature.

The arterial blood, charged with much heat which is not sensible, circulating through the small vessels, becomes venous, —acquires a dark hue, and its capacity for heat is diminished; consequently its temperature rises: the heat which was previously latent, is, from the decrease of capacity, sufficient to raise its temperature, and is evolved. In this mode, the loss of heat which occurs from the inferior temperature in which we live, is compensated. The fresh supply is taken in at the lungs, and brought into use in the minute vessels.

Of late, this theory has been brought into discredit, by the experiments of M. M. De la Roche and Berard, on the capacities of bodies for caloric, and by those of Mr. Brodie upon respiration. All experiments upon the capacities of bodies, by

heat, are very delicate and liable to error; and the conclusions of Crawford on this point, with respect to the gases, have been disproved by the French chemists.

Mr. Brodie cut off the communication between the brain and lungs of animals, and continued respiration artificially*. The usual chemical changes continued in the lungs upon the blood, nevertheless the temperature of the animals diminished, and even more rapidly than if the respiration had not been continued, owing, he says, to the succession of cool air sent into the lungs. He therefore concludes, that animal heat depends much more upon the nervous energy than upon the chemical changes of the blood. But many circumstances favor the doctrine of Crawford. In high temperatures we have less necessity for the evolution of heat, by the chemical changes of the blood and air; whereas, in low temperatures, as more heat is required, to sustain the natural degree of temperature, the chemical changes are more necessary; accordingly, in very high temperatures, the arterial blood remains arterial, is as florid in the veins as in the arteries, and the inspired air is less vitiated; in low temperatures the venous blood is extremely dark, and the inspired air more vitiated. Vide Crawford on Animal Heat, p. 387, et seq.

Dr. Crawford states, that the chemical process of respiration may, in certain cases, be the means of cooling the body. If the pulmonary exhalation is in very great abundance, it will carry off so much of the heat given out during the change of the oxygen into carbonic acid, that there may not be sufficient to saturate the increased capacity of the arterial blood; this will therefore absorb heat from the system, as it passes along, till its temperature equals that of the other parts. Animal Heat, p. 388.—Now, in Mr. Brodie's experiments, the influence of the brain was cut off from the lungs; these must have been

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* Philos. Trans. 1812.

weakened, and, as a most ingenious friend of the translator's remarked, the mouths of the relaxed vessels would consequently exhale vapour in great abundance, and carry off much of the heat, which ought to have assisted to saturate the increased capacity of the arterial blood; this must have acquired heat from the interior of the system, and the general temperature of the body of course fell. In the animals whose respiration was not kept up artificially, what fluid was secreted must have remained in the liquid form*, and, not being carried off by expiration, could not produce that diminution of temperature which was observed in the instances where respiration was artificially sustained.

It may not be improper to remark here, that Dr. Prout wrote a paper last year, in Dr. Thomson's Annals of Chemistry; and Dr. Fyfe published about the same time an inaugural Dissertation at Edinburgh, upon the variety of the quantity of carbonic acid gas formed in the lungs under different circumstances. The former found the quantity to increase from day break till noon, and then gradually diminish again till morning. The increase took place exactly at day break. Whenever the quantity had been diminished, it afterwards rose proportionally and vice versa. It was diminished, by whatever contained alcohol, by tea, depressing passions, fatigue, mercury, and probably during sleep.

An extensive set of experiments are necessary on this point, made at different ages, in different temperaments, climates, temperatures, and under every variety of circumstance.

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* Dr. Le Gallois (Experiences sur le principe de la vie. 246) actually found this invariably the case. "The lungs," he says, "are always found swollen and filled with a frothy fluid," after decapitation, or the division of the eighth pair. In his experiments, respiration was not supported artificially.

SECT. XI.

OF THE CUTANEOUS PERSPIRATION.

174. THE functions of the skin are so various, that they cannot all be described with advantage in one chapter, but each must be considered under that class of actions to which it belongs. For, in the first place, the skin is the organ of touch, which will be examined under the head of animal functions.

It is an organ of inhalation, and in this point of view belongs to the absorbent system, to be spoken of among the natural functions.

It is likewise the organ of perspiration, and on this account related to the function of respiration, and may very properly follow it in this place.

175. The skin consists of three membranes. The *corium*, internal; the *cuticle*, external; and the *reticulum*, between these.

176. The *cuticle* or epidermis, forms the external covering of the body, is separable into lamellæ, and exposed to the atmosphere, the contact of which can be borne by scarcely any other part, if you except the enamel of the teeth. For this reason, the internal cavities and the canals which communicate with the surface for the purpose of admitting air, especially the respiratory passages, the whole of the alimentary canal, the tongue, the inside

of the cheeks, and the organ of smell, are covered by a fine epithelium, originating from the epidermis.

177. The texture of the epidermis is extremely simple, destitute of vessels, nerves, and of true mucous web, and consequently but little organized; singular, however*, remarkably strong, considering its pellucidity and delicacy, so that it resists for a great length of time maceration, suppuration, and other modes of decay, and is reproduced more easily than any other of the similar parts.

178. It is completely sui generis, somewhat like a horny lamella, and adheres to the subjacent *corium* by the in-

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* The excessively dense epidermis of some animals consists of vertical fibres, which, in arrangement, somewhat resemble the structure of the Boletus igniarnis. Its internal surface is porous, and penetrated by the filaments, in appearance silken, of the subjacent corium. This is remarkably exemplified in a preparation now before me, taken from the balœna mysticete. The human cuticle, in certain diseased states, exhibits the same appearance as in the Englishman, called the Porcupine Man, who laboured by hereditary descent under a cuticular complaint, which he transmitted to his children and grand-children. Vide W. G. Tile's Beschreibung und Abbilddung der beiden sogenannten Stachelschwein-Menschen (Porcupine Men). Altenb. 1802. fol.

The innumerable polyedrical papillæ and horny warts which I witnessed upon every part of the skin of these brothers, excepting the head, the palms of the hands, and the soles of the feet, bore a strong resemblance to the skin of the elephant, especially about the vertex and forehead of the animal.

Similar also are corns, and the brawny cuticle of the feet, in those who walk barefooted. Vide Carslisle on the Production and Nature of Corns in the Med. Facts and Observations, vol. vii. p. 29.

tervention of a mucus, and by numerous very delicate fibrils, which penetrate the latter*.

The pores which Leuwenhoek imagined in it, do not exist; but it allows a very ready passage to caloric, carbon, hydrogen, and to matters composed of these, v.c. oil.

179. The importance of the cuticle to organized systems, is demonstrated by its universality in the animal and vegetable kingdoms; and by its being distinctly observable in the embryo from the third month after conception.

180. The inner part of the cuticle is lined by a fine mucous membrane, denominated from the opinion of its discoverer, *reticulum malpighianum*. This unites the cuticle more firmly to the corium†.

Its nature is mucous, it is very soluble, and, being thicker in Ethiopians, may be completely separated in them from the corium, and made to appear as a true membrane‡.

181. Our colour resides in it. In all persons the corium

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* W. Hunter, in Med. Observations and Inquiries, vol. ii. p 52, ag. tab. 1. fig. 1, 2. The conjecture of this eminent man, that the fibrils excrete the perspirable matter, is, I think, improbable.

† Hence I have found the Epidermis of Albinos separate easily by the heat of the sun; whereas in negroes, it scarcely does so on the application of a blister.

‡ Some of the moderns have assigned many laminæ, and even different kinds of laminæ, to the reticulum; as Lieutand in Essais Anatomiques, p. 103. ed. 1766; and Cruikshank, l. c. p. 43. 99.

Others make it inorganic. Vide Mich. Skielderup, l. c. p. 93.

is white, and in almost all the cuticle white and semi-pellucid; in Ethiopians, indeed, it inclines to grey. But the mucous reticulum, varies after birth, with age, mode of life, and especially with difference of climate.

181. Thus among the four varieties into which I would divide the human race, in the first, which may be termed Caucasian, and embraces Europeans, (except the people of Lappo and the rest of Finland,) the western Asiatics, and the northern Africans, it is more or less *white*.

In the second, or Mongolian, including the rest of the Asiatics, (except the Malays of the peninsula beyond the Ganges,) the Finlanders of the north of Europe, the people of Lappo, &c. and the Eskimoes diffused over the north of America, it is *yellow*, or resembling box wood.

In the third, the Ethiopian, to which the remainder of the Africans, except those of the northern parts of Africa, belong, it is *brown* or *fuliginous*.

In the fourth, or American, comprehending all the Americans, excepting the Eskimoes, it is almost copper coloured, of a dark *orange* or *ferruginous* hue.

In the fifth, or Malaic, in which I include the inhabitants of the islands in the Pacific Ocean, and of the Phillipine and Sundaic, and those of the peninsula of Malaya, it is more or less of a *bay* colour, between the hue of fresh mahogany and that of cloves and chestnuts.

All these shades of colour, as well as the other characteristics of nations and individuals, run so insensibly into one another, that all division and classification of them must be more or less arbitrary.

182. The essential cause of the colour of the Malpighian mucus, is the proportion of carbon which is excreted together with hydrogen from the corium; but in dark

nations being very copious, is precipitated upon the mucus and combined with it*.

183. The corium, which is covered by the reticulum and epidermis, is a membrane, surrounding and investing the whole body, and defining its surface; tough; very extensive; of different degrees of thickness; every where closely united; and, as it were, interwoven with the mucous tela, especially externally, but more loosely on its internal surface, in which, excepting certain parts, we generally discover fat.

184. Besides nerves and absorbents, innumerable blood vessels penetrate to its external surface, and are shewn, by minute injection, to form very close and delicate net works.

185. A vast number of sebaceous follicles are dispersed through it, which diffuse over the skin an oil, thin, limpid, and not easily drying, altogether distinct from the common sweat, and from that which possesses an odor resembling the odor of goats and is peculiar to certain parts only.

186. Lastly, almost every part of the corium is beset with various kinds of hairs, chiefly short and delicate, more or less downy, and found nearly every where but on the palpebræ, penis, the palms of the hands, and the

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* I have given this opinion at some length in my work, de gen. human. varietate nativa, p. 12, 209. ed. 3. Some eminent chemists accord with me, among whom, suffice it to mention the celebrated Davy, in the Journals of the Royal Institution, vol. ii. p. 30. "In the rete mucosum of the African, the carbon becomes the predominant principle; hence the blackness of the negro." W. B. Johnson, l. c. vol. ii. p. 229.

soles of the feet. In some parts, they are long, and destined for peculiar purposes; for instance, the scalp, the eye-brows, the eye-lashes, the vibrissæ, mustachios, beard, and the hair of the arm-pits and pudenda.

187. Man is universally less hairy than most other mammalia. But, in this respect, nations differ. For, not to speak of those nations who to this day anxiously pluck out their beard, others appear naturally destitute of hair; v. c. the Tunguses and Burats; on the other hand, creditable travellers assert, that some inhabitants of the Pacific and Indian Ocean, are remarkably hairy.

188. Nor is there less variety in the length, flexibility, colour, and disposition to curl, both in each class of men enumerated above, and in individuals, especially the Caucasians; v. c. the hair of the head in the Caucasians is rather dingy, or of a nut brown, inclined on one hand to yellow, on the other to black; in the Mongolians and Americans, it is black, stiffer, straight, and more thinly sown; in the Malays, black, softer, woolly, thick, and abundant; in the Ethiopians, black and curled; in individuals, the principal difference is in respect to temperament, which is intimately and invariably connected with the colour, abundance, disposition to curl, &c. of the hair; and there also exists a remarkable correspondence between the colour of the hair and of the iris.

189. The direction of the hairs is peculiar in certain parts, v. c. spiral on the summit of the head, diverging upwards in the pubis, on the exterior of the arm, as is commonly seen in some anthropomorphous apes, (v. c. in the satyr, and troglotys,) running in two opposite directions towards the elbow, i. e. downwards from the shoulder, upwards from the wrist; to say nothing of the eye-lashes and eye-brows.

190. The hairs originate from the inner surface of the corium, which abounds in fat. They adhere to it pretty firmly*, by a curious bulb, consisting of a double involucrum; the exterior vascular and oval, the interior cylindrical, apparently continuous with the epidermis, and sheathing the elastic filaments of which the hair is composed, and which are generally from five to ten in each.

191. The hairs are almost incorruptible, and always anointed by an oily halitus. Of all parts they appear most truly electrical. They are very easily nourished, and even reproduced, unless where the skin is diseased.

192. Besides the functions ascribed to the integuments in the former Section, must be enumerated their excretory power, by which foreign and injurious matters may be elinimated from the mass of fluids†.

This is exemplified in the miasmata of exanthematic diseases, in the smell of the skin after eating garlick, musk, &c. in sweat and similar phenomena.

193. What is most worthy our attention, is the transpiration of an aeriform fluid, denominated, after the

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* I suspect that the bulb is intended for support rather than for nourishment, from this circumstance, that the locks of hairs sometimes found in melicera and steatomata of the omentum and ovarium, some of which I have now before me, are usually destitute of bulbs, because they are not fixed, bnt lie naked in the fatty matter.

† Hence the danger of contagion from hairs, to which miasmata adhere for a great length of time. Vide Cattwright's Journal of Transactions on the Coast of Labrador. vol. i. p. 273. vol. ii. p. 424.

ingenious philosopher who first applied himself to investigate its importance, the *perspirabile Sanctorianum*, similar to what is expired from the lungs. It likewise is composed of various proportions of carbon, azot, and hydrogen, precipitates lime from water, and is unfit to support either flame or respiration.

194. The *sweat*, which seldom occurs spontaneously during health and rest, unless in a high temperature, appears to arise from the perspirable matter of Sanctorius, being increased in quantity by the excited action of the vessels, and from its hydrogen uniting with the oxygen of the atmosphere, and assuming the liquid form.

195. Upon the same hydrogen, variously modified by the accession of other elements and constituents, would seem to depend the natural and peculiar odor perceived in the perspiration of certain nations and individuals.

196. The quantity of matter perspired from the integuments which, in a well grown adult are equal to 15 square feet, cannot be accurately estimated, but is probably about two pounds in 24 hours (A).

NOTE.

(A) THE functions of the skin are still but imperfectly known. It is universally allowed to be an organ of excretion, and some few regard it as also an organ of absorption.

That the skin absorbs matters applied by friction none can doubt. But absorption, independent of friction, is rather problematical.

Dr. Currie's patient (Med. Reports, &c.) labouring under dysphagia, seated in the œsophagus, always found his thirst relieved by bathing, but never acquired the least additional weight. Dr. Gerard's diabetic patient (Rollo on diabetes) weighed no more after cold or warm bathing than previously.

Seguin found no mercurial effects from bathing a person in a mercurial solution, provided the cuticle remained entire: these, however, occurred when the cuticle was abraded.

The instance mentioned by the Bishop of Llandaff, of the boy at Newmarket, who had been greatly reduced, that he might ride one of the horses, and was found to have gained 30 ounces in weight, during an hour, though he had taken but half a glass of wine during the time, evidently proves absorption somewhere; and the opposers of the doctrine of absorption by the skin, contend that it must have occurred in the lungs.

If a vessel, containing atmospheric air, is applied to the skin, the oxygen is converted into carbonic acid gas. (Ellis's further Enquiries on the Changes produced in atmospheric Air, &c. p. 357.) The oxygen, it may be said, must have passed through the skin to unite with the carbon of the blood. But we know too little of this process, to assert it with confidence.

The strongest argument in favour of cutaneous absorption, is the presence of absorbents over all the surface.

The skin, like the lungs, constantly exhales aqueous vapor in greater or less abundance. But whether it produces changes on the atmosphere similar to those of respiration, is a question which has given rise to experiments attended by the most opposite results. The latest experiments on this point, unquestionably prove that the oxygen is converted by the skin into carbonic acid. (Ellis, as quoted above.)

SECT. XII.

OF THE FUNCTIONS OF THE NERVOUS SYSTEM IN GENERAL.

197. WE now come to the other class of functions termed animal (83), by which the body and mind are connected. They have obtained their name from existing in animal systems only, and to a greater extent than those properly denominated vital.

198. The principal organs of these functions are the brain, medulla spinalis, and the nerves originating from these sources. They may be referred to two classes, sensorial and nervous: the former comprehending all excepting the nerves and their immediate origin, and serving more directly as the connexion between the office of the nerves and the faculties of the mind.

199. Upon this division rests the beautiful observation of the illustrious Sommering, respecting the correspondence between the relative size of each class with the faculties of the mind.—That the smaller the nerves are, compared with the sensorial class, the greater is the developement of the mental faculties. In this sense, man has the largest brain of all animated beings,—if its bulk be compared with that of the nerves arising from it; but by no means, if its weight be compared with that of the whole body.

200. Besides the cranium, a threefold covering is afforded to the brain, viz. the dura and pia mater, and between these two, the tunica arachnoidea.

201. The dura mater, which lines the inside of the cranium, like a periosteum, forms various processes. By the falx it divides the hemispheres of the cerebrum and cerebellum; by the tentorium * it supports the posterior lobes of the cerebrum, and prevents their pressure upon the subjacent cerebellum.

In its various duplicatures it contains and supports the venous sinuses, and prevents their pressure. These receive the blood returning from the brain to the heart, the proportion of which to the rest of the blood, Zinn long ago very truly remarked, has been over-rated by physiologists.

202. Next to the dura mater lies the arachnoid, so named from its thinness. Its use is not exactly known; it is destitute of blood-vessels (5), and extended like the dura mater merely over the substance of the brain, without following the course of its furrows and prominences.

203. On the contrary, the membrane called pia mater

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* In the skulls of some mammalia, a remarkable lamina of bone penetrates a duplicature of the tentorium, and supports it. Cheselden (Anat. of the Bones, c. 8) supposes this bony tentorium to exist in certain feræ only; but it is found in the equine genus, the cercopithecus paniscus, the delphinus phocœna, &c. Its use is uncertain: that which is generally ascribed to it (Laur Nihell de cerebro Edinb. 1780, p. 4) of supporting the cerebellum in the leaping mammalia, is improbable, because we find it in animals also of slow motion, and not in the ibex, which moves with the greatest velocity.

by the ancients, closely follows the cortical substance of the brain, and possesses innumerable blood-vessels, which penetrate into the latter. Hence, if a portion of this membrane is detached, we find the external surface very smooth, while the internal is villous, and resembles the roots of moss.

204. The cerebrum and cerebellum are composed of various parts, differing in texture and figure, but unknown in their uses. The most remarkable are the four ventricles, in the two anterior and fourth of which is found the choroid plexus, but we are ignorant of its office *.

205. The substance of the brain is twofold: the one called cineritious, or cortical, though not always situated exteriorly; the other white, or medullary. Between the two, Sommering has detected a third substance, most conspicuous in the arbor vitæ of the cerebellum, and the posterior lobes of the cerebrum.

206. The proportion of the cineritious to the ~~cortical~~ medullary substance, decreases as age advances; being greater in children, less in adults. It is almost wholly composed of very fine vessels, both sanguiferous and colourless (92), of which some few penetrate into the medullary substance: the latter is composed, in addition to these vessels and a fine cellular substance, of a pultaceous parenchyma, which, if examined with glasses, exhibits no regular structure, and, upon chemical analysis, affords a peculiar matter, in some measure resembling albumen.

207. The brain, after birth, undergoes a constant and

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* The importance of this plexus is shewn in the dissection of maniacs, in whom it alone is very frequently found diseased.

gentle motion, correspondent with respiration; so that, when the lungs shrink in expiration, the brain rises, but when the chest expands, it again subsides *.

208. The spinal marrow is continuous with the brain, and may be said either to spring from the brain, as from a root, or, on the contrary, to terminate in it, and grow into its substance. Contained in the flexible canal of the vertebræ, it is enveloped by the same membranes as the brain: its substance is also twofold, but the medullary is exterior to the cineritious.

209. From these two sources, the brain and spinal marrow, arises the greater part of those chords, which are more or less white and soft, chiefly composed of cellular canals containing nervous medulla, and distributed throughout nearly all the soft parts: some nerves, however, may be more properly considered as uniting with the brain and spinal marrow, than springing from them.(A).

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* I once enjoyed the opportunity of observing this motion, and making some experiments with respect to it, in a young man eighteen years of age. When only five years old, he had fallen from an eminence, and fractured the frontal bone on the left side of the coronal suture. Since which time, there had been an immense hiatus, covered by merely a soft cicatrix and the cuticle. The hiatus formed a hollow, deeper during sleep, and varying according to the state of respiration: very deep if he retained his breath, much more shallow, and even converted into a swelling, by a long continued expiration. At the bottom of the hollow, I observed a pulsation synchronous with the pulsation of the arterial system, such as deceived Petriolus, Vandellus and the adversaries of Haller, who confounded it with that which depends upon respiration. I may add, that this wound on the *left* side of the head, had rendered the *right* arm and leg paralytic.

210. Besides the numerous experiments made by Haller and other very careful observers, we are certain, from minute anatomical examination, that many of the similar parts do not exhibit any true vestige of nerves; and from surgical observations*, and dissections of living animals†, that they do not evince the least sign of feeling.

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* In the great variety, and even contradiction of opinion, which, as we shall presently mention, exists in respect to the feeling of tendons and other parts when injured, I have always considered negative arguments of more weight than positive, because nothing is more fallacious than the ideas of patients as to the seat of internal pains. To say nothing of cases where amputated parts appear to the patient as still in possession of feeling, it is well known that some have felt a fixed pain for a great length of time, in parts where after death nothing uncommon was observable; and that, on the other hand, in chronic diseases, pain is sometimes not felt in the diseased part, but in another, which is healthy, and perhaps very remote.

We may much more easily explain syphilitic pains, referred to the bones, by this circumstance, than by so many contradictory experiments, in which I have seen the medulla roughly handled without causing the least uneasiness.

† I am every day more convinced that much caution and practice and repetition of the same experiment, in many different kinds of animals, are necessary in establishing the laws of physiology from dissections of living animals. To adduce the example of the supposed feeling of the medulla, I have found different results in many mammalia and birds. Many allowed the medulla to be destroyed without evincing any symptom of pain; others were convulsed, and cried out on the approach of the instrument. The latter might be agitated from the dread of fresh torment, on seeing the knife; and the former, having suffered great torture, might be insensible to the less violent irritation of the medulla, although it is endowed with nerves.

Such are the cellular substance, the epidermis, and reticulum mucosum, the hairs and nails.

The cartilages, bones, periosteum, and marrow.

The tendons, aponeuroses, and ligaments.

Most extended internal membranes, as the dura mater and arachnoid; the pleura, mediastinum, and pericardium; the peritonæum, also the cornea.

The greater part of the absorbent system, especially the thoracic duct.

Lastly, the secundines and umbilical chord.

211. The ultimate origin of most nerves from the brain cannot be detected. A question is agitated even at the present day, whether the nerves of each side arise from the same or the opposite portion of the brain. The latter opinion is countenanced by certain pathological phenomena, and the decussation of fibres in the medulla oblongata and conjunction of the optic nerves.

212. A continuation of the pia mater follows the medulla of the nerves in their commencement, in such a way, as to unite very delicately with the vascular cortex. But as soon as they have quitted the brain or medulla spinalis, their structure becomes peculiar, different from all the other similar parts. They form transverse folds, more or less oblique and angular, long since described by Mollinellus, who not inaptly compared them to the rugæ of the earth-worm, or the rings of the aspera arteria.

213. Their nerves, especially those which are remarkable, for instance, the intercostals and par vagum, are every-where distinguished by ganglia, or nodules of a compact structure and reddish ash colour, but with whose functions we are scarcely acquainted. I am most inclined to believe with Zinn, that they unite more intimately the nervous filaments which meet in them from various direc-

tions; so that each fibre passing out, is composed of a portion of every fibre that has entered in.

Nearly the same holds good with respect to the plexuses, which are produced by the union and reticulated anastomoses of different nerves, and by a similar contexture of filaments into which the nerves are split.

214. The ganglia and plexuses are most abundantly bestowed upon the spinal and intercostal or sympathetic nerve. The latter, united by a few delicate filaments only with the rest of the nervous system, constitutes a peculiar system, chiefly belonging to the involuntary functions. For this reason, Bichât, viewing it as presiding over *organic* life, distinguished it from the other nerves belonging to *animal* life, to use his own language.

215. The terminations of the nerves are no less concealed from us than their origins. Excepting a few, which spread out in the form of membranes, as the optic nerves, which become the retina; the portis mollis of the seventh pair, which forms a zone in the spinal lamina of the cochlea; the ultimate filaments of the rest penetrating into the viscera, muscles*, corium, &c. are so intimately blended with their substance as to elude observation.

216. The parts just described, viz. the sensorium and the nerves originating in it, and distributed throughout the body, constitute that system which, during life, is the bond of union between the body and the mind.

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* This remarkable phenomena was first accurately described by I. D. Schlichting in the Commes. litter. Noncum. 744, p. 402, 809; afterwards more fully in the Mem. Présentés à l'Ac. des So. de Paris, t. i. p. 113. Its causes were ingeniously discovered by experiments on living animals by Halle. His pupil's J. D. Walstaf's Exper. circa mot. cereb. cerebell. &c. Gotting. 1753.

217. That the mind is closely connected with the brain, as the material condition of mental phenomena, is demonstrated, to omit such arguments as the immediate connexion between the brain and the organs of sense, by our consciousness, and by the mental disturbances which ensue upon affections of the brain.

218. The singular situation and form before alluded to, of certain parts of the brain, and likewise some pathological phenomena, have induced physiologists to suppose certain parts the seat of the soul. Some have fixed upon the pineal gland*, others the corpus callosum†, the pons Varolii, the medulla oblongata, the corpora striata, and the water of the ventricles, which wash against the origin of some nerves. Others not contented with one spot, have assigned particular parts of the brain for individual faculties and propensities. (B).

219. The energy of the whole nervous system does not depend solely upon the brain. The spinal marrow, and even the nerves are possessed of their own powers, which are sufficient to produce contractions in the muscles. These powers are probably supported by the vascular cortex. In man, the powers proper to the nerves are less,

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* The Cartesian hypothesis received some weight from the dissection of maniacs, in whom the pineal gland was found full of calcareous substances. But more careful observation shewed, that, after the twelfth year, it was generally filled with a pearly sand, in the healthiest persons, though very seldom in animals. Sömmering de lapillis vel prope vel intra gland. pin. sitis, et de acervulo cerebri. Mogunt. 1785, 8.

† The prerogative of this part was ably refuted by Zinn. exp. circa corpus callosum, cerebellum, duram meningem, in vivis animalibus instit. Gott. 1749, 4.

and those depending upon the brain greater, than in animals, especially the cold-blooded.

220. The office of the whole nervous system is twofold. To excite motion in other parts, especially in the voluntary muscles, of which we shall hereafter speak at large; and to convey impressions made upon the organs of sense to the brain, and there to excite perception, or by means of sympathies to give occasion to reaction.

221. Experiment and observation put these functions of the nervous system beyond the reach of controversy. To unfold the nature of these functions is difficult indeed. (C).

222. Most opinions on this subject may be divided into two classes. The one class regards the action of the nervous system as consisting in an oscillatory motion. The other ascribes it to the motion of a certain fluid, whose nature is a matter of dispute; by some called animal spirits, and supposed to run in vessels; by others a matter analogous to fire, light, a peculiar ether, oxygen, electricity, or magnetism.

223. Although I would by no means assent to either of these opinions, I may be allowed to observe, that most arguments brought by one party against the hypothesis of the other, must necessarily be rude in proportion to the subtlety of the oscillations (if such exist) of the nerves or the nervous fluid.

224. These two hypotheses may, perhaps, be united, by supposing a nervous fluid thrown into oscillatory vibrations by the action of stimulants.

225. The analogy between the structure of the brain and some secreting organs, favours the belief of the existence of a nervous fluid. But tubes and canals are evidently no more requisite for its conveyance, than they are requisite

in bibulous paper, or any other matter employed for filtering.

The opinion receives much weight from the resemblance of the action of the nerves to the phenomena produced by the series of a galvanic apparatus and by the common electrical machine, in a living animal, or in parts not quite deprived of vitality. These phenomena in fact long ago induced some physiologists to compare the nervous to the electric fluid. The singular and undeniable effects attributed to animal magnetism, as well as other phenomena which have given rise to the belief of a kind of sentient atmosphere surrounding the nerves, agree very well with the same hypothesis.

226. If we regard the oscillation of the nerves, not as similar to that which occurs in tense chords, but of such a description as may be conceived to occur in the soft pulp of the brain, we shall find many physiological phenomena exactly corresponding with the supposition.

It is demonstrated that hearing depends upon an oscillation. In vision also it probably occurs, although not to the extent imagined by Euler.

The penetration of Hartley in following up the conjectures of Newton, has rendered it so probable, that the action of the other senses is not very dissimilar from this oscillating motion, that on the same supposition he very ingeniously explains, principally by means of the vapour of the ventricles (called by him the denser ether), first, the association of ideas, and again by the assistance of this, most of the functions of the animal faculties. (D).

NOTES.

(A) No part can be justly said to arise out of another. When the heart is absent, the arteries are equally present; in brainless fœtuses, the nerves are all found, even at their proper foramina, in the skull.

(B) Gall teaches that certain faculties and propensities reside in particular parts of the brain: that if they are strong, those parts are proportionably larger; and that the portion of skull lying immediately over such parts, must also be of greater size, on account of the enlargement of what is beneath. That the size of the exterior of individual parts of the skull, consequently indicates the force of individual mental qualities. The conclusions relative to each part are drawn from observing, that, in certain animals, remarkable for particular mental qualities, certain parts of the brain, and of the skull lying immediately above these parts, are singularly large, and from the very same thing being equally observable in all individuals of the human species, remarkable for the same qualities. Those enlargements of the surface of the skull, which do not arise from internal pressure, such as the frontal sinuses, the knob in the centre of the occipital ridge, evidently point out nothing relative to the brain.

This doctrine, perfectly original and extremely beautiful, is, I think, no less entitled to respect than Dr. Gall's metaphysics, and his admirable anatomical view of the nervous system.

(C) Blumenbach seems to regard the brain as the organ of mind, and the spinal marrow and the nerves directly united with it and the brain, as organs conveying the volition of the mind to the muscles, and as receiving or conveying to it the impressions made by objects on the senses: the ganglions and the nerves closely connected with them, as presiding over the involuntary

functions. Irritability he assigns with Haller to the muscles, as inherent, independent of nervous energy. (302 & seq. infra).

The celebrated Whytt of Edinburgh, opposed Haller strongly in this opinion with respect to irritability (Essay on the vital and involuntary motions. Physiological Essays. Treatise on Nervous Diseases.) His chief arguments were the following.

Irritation of a nerve causes contractions in the muscles to which it is distributed, and more forcibly than if the muscles themselves were irritated.—This is true in regard to the voluntary muscles; but Bichât could scarcely induce the least contraction in involuntary muscular parts, by stimulating their nerves. (Recherches Physiologiques.) Haller allows the nerves to convey the stimulus of the will to the voluntary muscles. This, however, is not sensibility. The stimulus of the voluntary muscles must be conveyed by the nerves from the brain; but the muscles must be already irritable; the stimulus of involuntary muscles is their contents; their stimulus is not derived from the brain, &c. therefore, on irritating their nerves, much contraction cannot be expected. Stronger muscular contractions follow irritation of a nerve than of a muscle, probably because the nerve conveys the proper stimulus of the muscles, and more equally diffuses it.

All sympathetic motions instantly cease when the communication with the brain is cut off.—All sympathetic motions of voluntary muscles cease, because the stimulus of these muscles is derived unquestionably from the brain; but Whytt has adduced no instance of this in involuntary muscles, (Nervous Diseases, p. 51,) viz. where the stimulus is not conveyed by nerves, but derived from their contents.

In *muscular* parts, irritability is in proportion to sensibility, which depends necessarily upon the nerves.—This is unanswerable, if it can be proved that the sensibility in question, which is confined to the part and not perceived by the mind, is dependent upon nerves.

Opium, which is known to destroy sensibility, destroys the

irritability of the heart if given to frogs, and much sooner if the brain and spinal marrow are entire than otherwise; shewing its influence by means of the nerves. Appendix to Whytt's Phys. Essays, p. 263. But Fontana and Dr. A. Wilson found contrary results.

Involuntary muscles, whose stimulus is their contents, are abundantly supplied with nerves; what can be their use but to afford something necessary for contraction? These parts, besides nourishing themselves are endowed with numerous sympathies, secrete various substances, and perform considerable and nearly constant muscular action. All these circumstances are no doubt intimately connected with the nerves. Blumenbach himself allows this with probably the exclusion of muscular action; but all the functions of these parts consist so much of muscular action, that this appears necessarily to claim the principal office of the nerves; and for this reason, while Blumenbach views with Bichât, the gangliac nerves as presiding over the involuntary functions, it is singular how he can agree with Haller in assigning irritability inherently to the muscles: so great a part of the involuntary functions depending on irritability.

The opinion that the involuntary functions are but little dependent on the brain and spinal marrow, is weakened by many arguments.

Every part of the body, perhaps except the hairs, nails, and cuticle, may, by an increase of irritation, become sensible. This could not be, unless a communication always existed between all parts and the brain. Again, affections of the mind derange every involuntary function.

In Mr. Brodie's late experiments, the secretion of urine ceased when the spinal marrow was divided, although the circulation was sustained artificially.

Dr. Le Gallois lately presented to the Imperial Institute of Paris, a most interesting set of experiments on this subject. He found that the life of any part of the trunk was destroyed

by the destruction of the corresponding portion of the spinal marrow; and that, indeed, general death ensued sooner or later, according to the greater or less height of the portion of spinal marrow destroyed, and the more or less advanced age of the animal: facts proving the importance of the nervous, although, indeed, not of the cerebral energy to the involuntary functions, which consist to so great a degree in the irritability of muscular structure. The motion of the heart was affected in common with the rest; circulation always ceased suddenly upon the destruction of the whole of the medulla spinalis; and although the heart did afterwards contract, its contractions were weak, and unable to support the circulation.

The great influence of the spinal marrow upon circulation, was farther established by tying up some of the arteries, so as to render less exertion necessary for the heart in propelling its blood, after the destruction of a part of the spinal marrow. Thus the life of the corresponding part of the body was prolonged. For life depends also in a great measure upon a due supply of arterial blood, which again depends upon the nervous influence upon the circulating system. The stomach he found under the influence of the brain. After the division of the eighth pair of nerves, the functions of the stomach were disturbed, and in guinea-pigs it could neither digest nor propel its contents. The breathing became gradually more difficult, and after death the lungs were found gorged with an abundance of serous fluid, and the blood-vessels turgid with blood.

It may not be very foreign to remark, that the affection of respiration was found to depend upon that portion only of the brain, from which the eighth pair arises. Dr. Le Gallois removed by slices, repeated from before backwards, the whole of the cerebrum and cerebellum, and even a portion of the medulla oblongata, without any ill effect upon respiration or circulation; but the moment the origin of the par vagum was removed, the dyspnæa commenced. This is strikingly confirmed by a case

of monstrosity, recorded in a very masterly paper by Mr. Lawrence, in the last volume of the Med. Chirurg. Trans. An acephalous child was born, which lived five days, voiding fœces and urine, taking food once, breathing regularly, and possessing our usual temperature; it probably died from starvation. On dissection, the spinal marrow was seenterminating about an inch above the foramen magnum in a small bulb which gave origin to the nerves from the fifth to the ninth. This case proves the independence not only of respiration, but of animal heat upon the cerebral mass in general.

(D) These oscillations are purely hypothetical, and indeed improbable: were their existence proved, we should know nothing more of the real nature of the cerebral functions.

SECT. XIII.

OF THE EXTERNAL SENSES IN GENERAL, AND OF TOUCH IN PARTICULAR.

227. WE find the other function of the nerves to consist in communicating to the sensorium the impressions made by external objects. This is accomplished by the external senses, which are, as it were, the watchmen of the body, and the informers of the mind.

The latter alone belong to our present subject. For to regard, with Gorter, the stimulus which inclines us to relieve the intestines, the sensation of hunger, and other internal calls of nature, as so many distinct senses, is unnecessary minuteness, as Haller long since observed.

228. *Touch* merits our first attention, because it is the first to manifest itself; its organ is most extensively spread over the whole surface, and it is affected by most properties of external objects.

229. For we perceive not only some qualities, as heat, hardness, weight, &c. by the touch alone; but our knowledge obtained by other senses, respecting some qualities, is rendered more accurate by the touch; such are figure, distance.

230. It is less fallacious than the other senses, and by culture capable of such perfection, as to supply the defects of the others, particularly of vision.

231. The skin, whose structure we formerly examined,

is the general organ of touch. The immediate seat is the papillæ of the corium, of various forms in different parts, commonly resembling warts, in some places fungous, in others filamentous. The extremities of all the cutaneous nerves terminate in these under the form of pulpous penicilli.

232. The hands are the principal seat of touch, properly so called, and regarded as the sense which examines solidity. The skin of the hands has many peculiarities. In the palms and on each side of the joints of the fingers, it is furrowed and free from hairs, to facilitate the closing of the hand. The extremities of both fingers and toes are furrowed internally by very beautiful lines more or less spiral; and are shielded externally by nails.

233. These scutiform nails are bestowed upon man only and a few other genera of mammalia (upon the quadrumana, which excel in the sense of touch)*, for the purpose of resisting pressure, and thus assisting the action of the fingers, while we are examining objects.

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* Simiæ, papiones, cercopitheci & lemures, the apices of whose fingers in their four hands are very soft and marked as in the human subject with spiral lines. Physiologists have disputed whether the sense of touch is bestowed on any besides man and the quadrumana. In determining this controversy we must recollect what was formerly said (81) concerning the difference of condition, according to the mode of living. On one hand, I would grant to both parties, that the snowy hands of a delicate girl must enjoy a much more exquisite sense of touch, than what I called the fingers of animals. But, on the other hand, I have frequently seen simiæ and papiones possessing much softer fingers, and using these fingers to explore surfaces much more dexterously than many barbarous nations, and the lower orders of Europeans, whose hands have become hardened from labour.

They are of a horny nature, but on the whole very similar to the epidermis. For under them lies the reticulum, which in negroes is black; and under this is found the corium, adhering firmly to the periosteum of the last phalanx. These constituent parts of the nails are striated lengthwise. The posterior edge, which, in the hands, is remarkable for a little lunated appearance, is fixed in a furrow of the skin; and the nails are growing constantly from this, so as to be perfectly renewed every six months.

SECT. XIV.

OF TASTE.

234. WE perceive tastes by the tongue and in some degree by the other neighbouring cutaneous parts of the mouth; especially by the soft palate, the fauces, the interior of the cheeks and lips: by the latter, however, we taste only what is acrid and bitter.

235. The chief organ of taste is the tongue, agile, obsequious, changeable in form, and, from its remarkable fleshy nature, not unlike the heart.

236. Its integuments resemble the skin. They are an epithelium, performing the office of cuticle; the reticulum Malpighianum*; and a papillary membrane, but little different from the corium.

237. The integuments of the tongue differ from the skin chiefly in these respects.—That the epithelium is moistened not by the oily fluid of the skin, but by a mucus which proceeds from the foramen cæcum of Meibomius, and the rest of the glandular expansion of Morgagni.—And secondly, in the conformation of the papillæ, which are commonly divided into petiolated, obtuse, and conical. The first are situated in a lunated series at the root of the

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* In dogs and sheep with variously coloured skin, I have commonly found the reticulum of the tongue and fauces also of various colours.

tongue; the others, of various magnitudes, lie promiscuously upon the back of the tongue, and chiefly upon the edges and apex, where the taste is most acute.

238. These papillæ are furnished with filaments of the lingual branch of the fifth pair; and through them probably acquire the power of tasting. The ninth pair and the branch of the eighth appear intended rather for the various movements of the tongue, in manducation, deglutition, speaking, &c.

239. For the tongue to taste properly, it must be moist, and the substances to be tasted must be liquid, holding salts in solution. For if either is in a dry state, we may perceive the presence of the substances by the common sense of touch, but not be able to discover their sapid qualities. When the tongue tastes very accurately, the papillæ around its apex and margins are in some degree erected.

SECT. XV.

OF SMELL.

240. WHILE taste and smell are related by the proximity of their organs, they are not less so by the analogy of their stimuli, and by some other circumstances. For this reason, they have been generally named chemical or subjective senses.

By smell we perceive odorous effluvia, taken in by inspiration, and principally applied to the Schneiderian* membrane, which invests both sides of the septum narium and the convexities of the turbinated bones.

241. Although the same mucous membrane lines the nostrils and their sinuses, its nature appears different in different parts.

Near the exterior openings it is more similar to the skin, and is beset with sebaceous follicles, from which arise hairs, known by the name of vibrissæ.

Near the septum and the turbinated bones it is fungous, and abounds in mucous cryptæ.

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* Conr. Vict. Schneider de osse cribriformi et sensu ac organo odoratus. Witteb. 1655. 12.

This classical work forms an epoch in physiological history, not only because it is the first accurate treatise on the function of smell, but because it put an end to the visionary doctrine of the organ of smell being the emunctory of the brain.

In the frontal, ethmoidal, sphenoidal, and maxillary sinuses, it is extremely delicate, and supplied with an infinite number of blood-vessels, which exhale an aqueous dew.

242. It appears the principal, not to say the sole use of the sinuses*, to supply this watery fluid, which is perhaps first conveyed to the three meatus of the nostrils, and afterwards to the other parts, preserving them in a constant state of moisture, which is indispensable to the perfection of smell. The sinuses are so placed, that, in every position of the head, moisture can pass from them into the nostrils.

243. The principal seat of smell,—the fungous and nasal portion of the membrane, besides numerous blood-vessels, remarkable for being more liable to spontaneous hemorrhage than any others in the body, is supplied by nerves, chiefly the first pair, which are distributed on both sides of the septum narium, and also by two branches of the fifth pair. The former appear to be the seat of smell†: the latter to serve for the common feeling of the part, which excites sneezing, &c.

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* In my Prolus. de Sinibus frontal. Gotting. 1779. 4. I have brought forward many arguments from osteagony, comparative anatomy, and from pathological phenomena, to prove that these sinuses contribute indeed to the smell, but little or nothing to voice and language, as was believed by many physiologists.

† This is shewn by pathological dissection and comparative anatomy. Thus in Loder's Observ. tumoris scirrhosi in basi cranii reperti. Jen. 1779. 4. is a case of anosmia, following a compression of the first pair, by a scirrhus. We are taught, by comparative anatomy, that in the most sagacious mammalia, v. c. elephants,

244. The extreme filaments of the fifth pair do not terminate in papillæ, like the nerves of touch and taste, but in the spongy and equal parenchyma of the nasal membrane.

245. The organ of smell is very small and imperfect at birth. The sinuses scarcely exist. Smell consequently takes place but late,—when the internal nostrils are evolved, and is more acute in proportion to their size and perfection*.

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bears, dogs, bisulcous ruminants, hedgehogs, &c. the horizontal plate of the cribriform bone is very large, and perforated by an infinity of small canals, each of which contains a filament of the olfactory nerve.

* While animals of the most acute smell, have the nasal organs most extensively evolved, precisely the same holds in regard to some barbarous nations. For instance, in the head of the North American Indian, (a leader of his nation, and executed at Philadelphia 50 years since,) which I have given in the first decade of my collection of the crania of different nations, tab. ix, the internal nares are of an extraordinary size, so that the middle conchæ are inflated into immense bullæ; and the sinuses, first described by Santorinus, which are contained in them, I never, in any other instance, found so large

Next, in point of magnitude, are the internal nares of the Ethiopians, from among whom I have seven heads now before me, very different from each other, but the nasal organ is in every one much larger than we find it described by Sommering to be in that nation, über die körperl. Verschiednh des Negers, &c. p. 22. These anatomical observations accord with the accounts given by most respectable travellers concerning the wonderful acuteness of smell possessed by these savages.

246. No external sense is so intimately connected with the sensorium and internal senses, nor does any one influence them so much, as the sense of smell.

No other is so liable to idiosyncrasies, nor so powerful in exciting and removing syncope.

Nor is any other capable of receiving such delicate and delightful impressions; for which reason, Rousseau very aptly called smell, the sense of imagination.

No sensations can be remembered in so lively a manner as those of peculiar odors.

SECT. XVI.

OF HEARING.

247. SOUND, which is excited by the collision of elastic bodies, and propagated by the air, is first received by the conchiform cartilaginous external ear, which some few have the power of moving. In this it is collected; then conveyed into the meatus auditorius, which is anointed by a bitter cerumen; and strikes against the membrana tympani, which is placed obliquely in a circular furrow of the temporal bone, and separates the meatus from the internal ear.

248. Behind this membrane lies the middle portion of the ear,—the cavity of the tympanum, whose fundus is placed upwards and inwards.

It contains three* little bones: of which the exterior, or malleus, adheres by its manubrium to the membrana tympani, is generally united in the adult to the circular furrow, by its spinous process, and lodges its round head in the body of the incus. The incus is united to the head of the stapes, by the extremity of its long process, which extends across the cavity of the tympanum.

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* The existence of a fourth bone, (called Lenticular,) believed since the time of Franc. Sylvius, I have disproved at length in my Osteology, p. 155. et seq. edit. 2. It is wanting in the greater number of perfect preparations made from adults.

The stapes resting its base upon the fenestra ovalis, runs towards the vestibule of the labyrinth, into which, sounds, struck against the membrana tympani, are propagated by the intervention of these three little bones.

249. The Eustachian tube runs from the interior of the fauces into the cavity of the tympanum: so likewise the inferior scala of the cochlea,—the opening of the latter, termed fenestra ovalis, is closed by a peculiar membrane. The true use of each is not sufficiently known*.

250. In the deepest part of the petrous bone is placed the internal ear, consisting of three parts.

First, of the vestibule, placed in the centre, into which opens not only the fenestra ovalis, but the five orifices of the semi-circular canals, which lie posteriorly; and the superior scala of the cochlea, placed anteriorly.

The vestibule and semi-circular canals loosely contain very delicate membranous bags, lately discovered by the celebrated Scarpa. Two of these lie in the vestibule, and three in the semi-circular canals.

251. They, as well as the cavity of the cochlea, contain a very limpid fluid, bearing the name of Cotunnius, who shewed it to be absorbed by two canals, by him denominated *aqueducts*, by the no less illustrious Meikel, *diverticula;* the one arises from the vestibule, the other from the inferior scala of the cochlea.

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* Comparative anatomy renders it probable that the Eustachian tube is subservient to the action of the membrana Tympani. It is found in all red-blooded animals which possess a membrana tympani: but is wanting in fishes which are destitute of this membrane. The different opinions respecting its use, may be found in Keil's Archiv. für die Physiol. t. ii. p. 18. iii. p. 165. iv. p. 185. viii. p. 67. ix. p. 320.

252. The portio mollis of the seventh pair, together with the portio dura, (which afterwards runs along the Fallopian aqueduct,) having entered the internal acoustic opening, transmits its medullary filaments into the lower and cribriform part of the bone. These filaments run to the vestibule and semi-circular canals; but especially to the base of the cochlea, where they form a medullary zonula, marked by beautiful plexiform striæ, running between the two laminæ of the septum cochleæ.

253. The oscillatory tremor, which we formerly followed as far as the fenestra ovalis (248), is propagated to the vestibule, and, by means of the water of Cotunnius (251), strikes the auditory nerves distributed among the windings of the labyrinth.

254. Besides the muscles of the malleus and stapes, supposed to be voluntary, the chorda tympani, which is placed between the handle of the malleus and the longer leg of the incus, is believed to moderate the force of sound struck against the membrana tympani, and propagated along the cavity of the tympanum.

SECT. XVII.

OF SIGHT.

255. THE instruments of vision, the eyes, are two moveable globes, fixed to the optic nerves, whose decussation we formerly noticed (211), as it were to stalks, in such a manner, that their insertion is not exactly opposite the centre of the cornea and iris, but behind this imaginary axis, rather nearer to the nose.

256. They consist of various coats, containing humors of different degrees of density, so placed that the rays of light can pass from the transparent anterior segment to the opposite part of the fundus.

257. The external coat is called sclerotic. It is deficient in the centre, and that part is filled up by the cornea, which is transparent, lamellated, more or less convex, and projects like the segment of a small globe from one of larger size.

258. The interior of the sclerotica, is lined by the chorioid, which abounds in blood-vessels, especially vorticose veins, and is dyed on each side by a black pigment, adhering however but loosely to its concave surface in the form of mucus.

259. The chorioid contains the internal coat—the retina, —a medullary expansion of the optic nerve, which passes

through the sclerotica and chorioid. Its structure is very beautiful*.

In the imaginary axis of the eye, between the two principal branches of the central artery, it is perforated by the singular foramen of Sömmerring, which is surrounded by a yellow edge†.

260. The anterior edge of the chorioid is terminated by a cellular belt, called *orbiculus ciliaris*, by which it adheres firmly to a corresponding groove in the sclerotic; and from which two other membranes, viz. the iris and ciliary processes, are expanded in a circular form.

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* The beautiful blood-vessels of the retina were first discovered by Mery to be visible in a living cat plunged into water. Mem. de l'Acad. des sc. de Paris, avant 1699, t. x, p. 656; and 1704, p. 265.

The radiated surface of the retina in the hare is displayed by Zinn, in an admirable plate. Comm. soc. scient. Gotting. t. iv, a. 1751, tab. viii. fig. 3.

By Fontana, in the rabbit. Sur le venin de la vipere, vol. ii. tab. v. fig. 12.

† As I have discovered this central aperture in no animal besides man, except the quadrumena, the axes of whose eyes are, like the human, parallel to each other, I have thought its use corresponded in some degree with this parallel direction of the eyes, and have endeavoured to explain the correspondence, in my Handbuch der vergleichenden Anatomie, p. 547, et seq.

As, on the one hand, this direction of the eyes renders one object visible to both at the same time, and therefore more clearly visible; so, on the other, this foramen prevents the inconvenience of too intense a light, if it is probable that it expands and dilates a little, and thus removes the principle focus from the very sensible centre of the retina.

261. The *iris*, (whose posterior surface is lined by a brown pigment, and termed uvea,) lies anteriorly to the ciliary processes, is flat, and washed on all sides by the aqueous humour; narrower towards the nose, broader towards the temples. Its texture is dense and cellular, and contains no vestige of muscular fibre. We must regard it, with Zinn, as a membrane sui generis, and not as a propagation from the chorioid. The anterior surface is differently coloured in different persons, and, during life, counterfeits a flocculent appearance.

262. The blood-vessels of the iris run chiefly on its anterior surface, and are continued in the fœtus into the *membrana pupillaris**, which begins to open in the centre, at the seventh or eighth month of pregnancy, when the eyes have acquired some degree of size; and when, probably, the elliptic arches of its vessels begin to be gradually retracted into the internal ring of the iris, which I have never been able to perceive distinctly before that period.

263. The other circular membrane (260) bears the name of *ligamentum* or *corpus ciliare;* is more distant from the iris, and inclines backwards. Its external edge is thick†, and adheres to the ciliary circle (260): the in-

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* This beautiful membrane was first discovered by Francis Sandys, a celebrated maker of anatomical preparations, and first described and exhibited in a plate by Ever. J. Wachendorf Commerc. Litter. Nor. 1740. Hebd. 18.

† The ciliary canal, first described by Fel. Fontana, (sur le venin de la vipere, vol. ii. tom vii. fig. 8, 9, 10,) and afterwards more accurately by Adolp. Murray, (nov. actor. Upsaliens. vol. iii,) runs, in bisulcous animals, along this thick edge.

ternal is thin, and adherent to the margin of the capsule of the lens. The brown pigment is copiously diffused over it.

Its anterior surface, lying opposite to the uvea, is striated. The posterior, lying upon the vitreous humour, is beautifully separated into about 70 flocculi, remarkable for an indescribably minute and elegant set of blood-vessels. These flocculi are named ciliary processes, and their use is still an object of enquiry.

264. In the bulb of the eye are contained the humours, of three principal kinds.

The posterior, and by far the larger portion of the globe, is filled by the vitreous humour, proportionally larger in the human subject, especially after puberty, than in other animals, and so dispersed in innumerable drops throughout the cells of the delicate hyaloid membrane, that this membranaceo-lymphatic body has the appearance of a tremulous jelly.

265. Its ciliary zone surrounds and adheres to the capsule containing the crystalline lens, around which lies the water of Morgagni. The lens itself is very pellucid and cellular, but so much more dense than the vitreous body, that it feels between the fingers like a very tenacious gluten, although amazingly clear. The nucleus is more dense than the exterior lamellæ. These may, by management, be reduced into extremely delicate fibres, converging from the circumference to the centre. In the adult the lens is proportionally smaller than in quadruped mammalia; also less convex, especially on its posterior surface.

266. The remaining space of the eye is filled by the *aqueous humour*, which is very limpid, and divided by the iris into two *chambers;* the anterior and larger

separating the cornea and iris; and the posterior, in which the uvea lies towards the corpus ciliare, so small, as scarcely believed by some to exist.

267. These most valuable parts are defended from injuries, both by the profundity of their situation in the orbits, and by the valvular coverings of the eye-lids.

In the duplicature of the palpebræ, the *sebaceous follicles* of Meibomius, lie thickly distributed; and their edges are fringed by a treble or quadruple series of *cilia*: the cartilaginous tarsi serve for their support and expansion, and also facilitate their motion upon the eye-ball.

Above the eye-lids, to use the words of Cicero, the skin is covered by the *supercilia*, which preserve the eyes from the sweat flowing from the head and forehead, and in some measure screen them from too strong a light.

268. To lubricate the eyes, to preserve their brightness, and wash away foreign matters, is the office of the *tears*. Their chief source is a conglomerate gland placed in the upper and exterior part of the orbit. It has numerous but very fine excreting ducts, which are said to discharge about two ounces of tears upon each eye during twenty-four hours; the tears are afterwards absorbed by the puncta lachrymalia, the function of which may, in a certain sense, be compared to that of the lacteals in the villous coat of the small intestines: from the puncta they are conveyed through the snails horns, as they are called, into the lachrymal sac, and then pass into the lower meatus of the nostrils.

269. Thus much it was necessary to premise upon the structure of the organ of vision. We now come to the function of the organ,—to the explanation of vision.

The rays of light falling upon the cornea at an angle more acute than forty-eight degrees, pass through it, and from both its density and figure are considerably refracted; on entering the aqueous humour they again suffer refraction, but in a less degree.

Those rays which penetrate the pupil and are received by the lens, are still more refracted on account of the greater density of this medium.

The less density of the vitreous humour prevents the focus of rays from being too small, but allows it to fall elongated upon the retina, and exhibit the image of objects, inverse indeed necessarily from the laws of light.

270. The focus which, in this mode, falls upon the retina, is considered as acute, not absolutely but relatively, on account of the different refrangibility of colours; but the latitude arising from this aberration, is so small, that it not only does not obscure the clearness of vision, in any perceptible degree, but is the source of many advantages.

271. The celebrated question, why we behold objects erect, while their image is painted inversely upon the retina, may be easily answered, by considering that objects are called inverse in relation only to those which appear erect.

Now, since the images of all objects and of our own bodies are painted on the retina, all in their relative situation, their relative situation must correspond as exactly as if they were viewed erect, so that the mind (to which a sensation excited by the image and not the image itself is communicated) is preserved from all danger of error.

272. Since many conditions are required for distinct vision, the Creator has wonderfully ordered the functions

of these organs. A sufficient, but, at the same time, a definite quantity of light, not too intense for distinct vision, is provided in two modes:—First, according to the greater or less intensity of the rays, a less or greater number of them passes to the lens:—Secondly, that portion which is superabundant and injurious to vision is absorbed. The first is effected by the motion of the iris; the second, by the pigmentum nigrum.

273. The iris is endowed with sufficient mobility to accommodate itself to the intensity and distance of light, that when exposed to a strong light or near objects, it may expand itself, and contract the pupil, but when to a weaker light or more remote objects, it may contract itself and dilate the pupil. Physiologists have given different explanations of this motion. Some ascribe it to the impulse of blood into its vessels, others to contraction of its imaginary muscular fibres. I have shewn, in a particular treatise, that both these circumstances are impossible, and that it is by far more probable and natural to ascribe it to the *vita propria* of the iris (42); the more remote cause, as we formerly hinted (56), is to be sought for solely in the reaction of the sensorium.

274. The function of the dark pigment, so frequently mentioned, (258, 261, 263,) viz. to absorb the superfluous rays, and its importance to the perfection of vision, are demonstrated by the dissection of different kinds of animals, and by the diseased condition of Albinos, whose eyes are very tender and impatient of light from the absence of this pigment.

275. The focus of rays must fall exactly on the retina, neither produced beyond it, nor so short as to strike on the vitreous body. The latter defect exists in short-

sighted persons, from the too great convexity of the cornea, or gibbosity of the lens. The former is the defect of long-sighted persons, in whom there is the opposite conformation of parts.

276. Since a perfect and sound eye beholds near and remote objects with equal distinctness, it must of necessity be supplied with appropriate powers of accommodation. I am clearly convinced that these internal changes of the eye are chiefly accomplished by the pressure of the straight muscles of the ball, from this among other arguments,—that in the Greenland whale, an amphibious animal, which must see in media of different densities, nature has most accurately provided for this, in the remarkable structure and obsequious flexibility of the sclerotica.

277. During the waking state, the eyes are perpetually, although insensibly, agitated, and directed towards the axes of objects.

For, although the whole of the retina is sensible, it is not all equally calculated to receive the images of objects.

In the first place, the true axis of the human* eye, where the optic nerve enters, is proved by the well-known experiment of Mariott, to be nearly insensible to light. The principal focus of the other part of the retina, and which must be considered as the chief instrument of dis-

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* I say the human eye; for in some animals now before me, the seal and porcupine, for instance, the true and imaginary axis are the same, the optic nerve lying exactly opposite the centre of the cornea and pupil.

tinct vision, falls upon an imaginary axis of the globe, corresponding with the axis of the cornea and the whole eye. This, however, as Keinster observes in opposition to Boerhaave, is not to be understood as if only one point of an object could be seen distinctly at once, while the eye is fixed, and that, to behold another point, the axis of the eye must be changed. For the sensation of a complete object is simple and complete.

278. The habit of directing the axis of the eyes rapidly towards objects, is acquired by practice. This is proved by the instance of persons who were born blind, but have recovered their sight after puberty; and of children, who seldom acquire this facility of motion before the third month.

279. To habit we must ascribe also the circumstance of beholding an object singly, although we have two eyes. For infants at first see double, and the double vision which occasionally remains after certain diseases of the eyes, may be removed by practice and experience.

280. The combined power of the two eyes does not exceed, according to Jurin, that of each, by more than one tenth part.

It is needless to add, what the celebrated painter, Leonardo da Vinci, long since remarked, that in viewing distant objects, it is preferable to employ but one eye.

281. Sight can never occur, unless the angle of vision is at least more than 34 seconds. This was proved by the very beautiful experiments of the acute Mayer, who formerly was one of our number. And he demonstrated the great excellence of the human sight, by shewing that this still remained the limit of vision under any

light, under the splendor of the meridian sun, and the gloom of a dark lantern; so that vision remains almost equally clear, although the light be considerably increased.

282. We may hence infer the prodigious minuteness of the images of objects projected upon the retina, and nevertheless impressed so forcibly upon it, that, under certain circumstances, their vestiges remain, after the removal of the objects from before the eye.

SECT. XVIII.

OF THE VOLUNTARY MOTIONS.

283. WE have seen that the nerves perform two offices: the one of feeling, the other of moving. The former we have already considered; we shall now say something with respect to the latter.

284. All the motions of the body may be divided into voluntary and involuntary; the pulsation of the heart, the peristaltic motion of the intestines and other viscera, are commonly adduced as instances of involuntary motion. The action of by far the greater number of the other muscles is voluntary.

Respiration, sneezing, the tension of the membrana tympani, the action of the cremaster, are regarded by some as belonging to the former class; by others, to the latter; and by others, as of a mixed nature.

285. If this division is narrowly examined, it will be found embarrassed by so many difficulties, that the limits of each class cannot well be determined.

For, on the one hand, few functions can be termed truly involuntary, if we consider the connexion of the imagination and passions with the will.

Again, on the other hand, there are few voluntary motions that may not be rendered involuntary by the force of habit, whose influence upon our animal motions is immense.

286. Of this description are those muscular motions which, although generally voluntary, take place under certain circumstances, without the knowledge of the mind, or even in opposition to its endeavours.

Thus we wink involuntarily, if a friend suddenly approaches his finger to one of our eyes, though it does not come in contact: the ring finger generally bends if we bend the little finger.

We often move our limbs while sleeping soundly. On the contrary, muscles which have been long obedient to the will, occasionally cease to be so; an instance of this exists in the difficulty which we experience in attempting to move the hand and foot of the same side in different directions; and in all those motions, which, although voluntary and perfectly easy, if produced separately, are found very difficult if attempted together.

287. Among those motions which are supposed perfectly involuntary, no one is free from exception, as far as I know, excepting the spasms of the uterus during labour*.

With respect to the motion of the heart, we have the indubitable testimony of Baynard and Cheyne, that they saw the famous English officer, who could stop the motion of the heart and arteries at pleasure.

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* These are partly voluntary in some warm-blooded animals, as shewn in birds when setting, which, if deprived of their eggs, lay others in succession.

There is no question that the pulsation of the heart ca be accelerated or retarded by the varied state of respiration.

The motion of the stomach is voluntary in all ruminants, and I myself once distinctly found it voluntary in one instance.

Although the motion of the iris is involuntary in most persons, I have been credibly informed that some have been able, by a considerable effort, to subject it to the will, and contract the pupil in a faint light. So numerous are the motions commonly called involuntary, which become voluntary in some particular individuals, especially if aided by attention and the liveliness of imagination.

Thus I have seen some able to produce a spasmodic horripilation of the skin, by representing some unpleasant sensation to their imagination: others have had the power of exciting local sweat in the hands, &c.

288. This may perhaps be explained on the principle of sensorial reaction, which may be produced by imagination,—a mental stimulus, as easily as by a corporeal stimulus acting upon the sensorium. Many phenomena accord admirably with this explanation; v. c. the various causes of the erection of the penis, and of the flow of saliva.

289. The voluntary motions are the distinguishing characteristics of the animal from the vegetable kingdom. For no plant has been discovered, procuring for itself food by means of voluntary motion; nor any animal incapable of locomotion, or at least of procuring sustenance by the voluntary motion of some one limb.

290. In ourselves, these motions afford a striking proof

of the intimate harmony subsisting between the body and the mind; and which is demonstrated in the rapid and various motions of the fingers of a good performer on the harp, and of the vocal organs whenever we speak*.

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* A person playing on the harp, dancing, and singing, at the same time, exercises about three hundred muscles at once. G. Ent animad. in Thrustoni diatribam, p. 130.

SECT. XIX.

OF THE INVOLUNTARY MOTIONS.

291. THE organs of motion, by far the most numerous in the body, are the *muscles*, which form the greatest bulk among all the similar parts.

292. They abound in azote more than other animal parts; and the absence of this principle from the combination of hydrogen and carbon, which exists during health, entirely converts them under a particular morbid affection, and after death, into an adipocerous substance, resembling soap or spermacete.

293. The muscles are distinguished from other similar parts by two characteristic features; the one derived from their structure, the other from their singular vital powers.

294. This fleshy substance is so constructed of moving fibres, sui generis, and of a very faint red colour, that every muscle may be resolved into fibrous bands, these into bundles of fibres, and these again into very fine fleshy fibrils.

295. Every muscle possesses a covering of cellular membrane, which is so interwoven with its substance, as to surround the bands, the bundles, and even each particular fibril.

296. Every part of the muscles is amply supplied with blood vessels and nervous threads. The latter appear to deliquesce into an invisible pulp, and unite intimately with the muscular fibres: the former are so interwoven with the fibres, that the whole muscle is red, and acquires its own paleness only by being washed.

297. Most muscles terminate in tendons, which are fibrous parts, but so different in colour, texture, elasticity, &c. as to be readily distinguished from muscles: thus disproving the opinion of some, that the tendinous fibres originated from the muscular. This error arose, no doubt, from the circumstance of the muscles of infants containing a greater number of fleshy fibres, in proportion to the tendinous, than those of the adult.

298. The other exclusive character of muscles (293) is the irritability of Haller*, the motion of which, and its difference from contractility, I formerly explained (41), but shall now prosecute farther.

299. This irritability, or muscular power, or vis insita, is bestowed upon all muscles, but in different degrees.

300. The highest order are the hollow muscles, which perform the vital and natural functions, and especially the

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* I thus distinguish it, not because the luminary of the Gottingen school first discovered it, for he repeatedly bestowed praises upon the opinions entertained with regard to it by his predecessors, since the time of Glisson; but because he first investigated it as it deserved, illustrated and enlarged upon it by numerous living dissections, and demonstrated the great power and influence of the doctrine thus remodelled, upon the animal economy. I have also another reason, viz. to distinguish it from the irritability of the truly meritorious Gaubius, who applied the same term to the morbid sensibility of the living solid.

heart, whose internal surface enjoys a very lively and permanent irritability.

Next to the heart follows the intestinal canal, particularly the small intestines, which in warm-blooded animals contract after the heart has ceased to show signs of irritability.

Next the stomach.

Then the urinary bladder, &c.

Among the other muscles, the respiratory, v. c. the diaphragm, the intercostals, and triangularis sterni, are remarkable for their irritability.

Then follow the remaining muscles.

Less, but still, however, some, exists in the arteries (128).

Also in the venous trunks contained in the thorax (95).

Still less, if it deserves the name of irritability, in the other blood vessels.

301. Haller, the great arbitrator in the doctrine of irritability, has ascribed it, improperly, I think, to some parts possessed indeed of contractility, but in which I have never been able to detect genuine irritability.

Such are the lacteals, glands, gall bladder, uterus, the dartos, and the penis.

And others, with no less impropriety, bestow it upon the iris, the external surface of the lungs, &c. in which it no more exists than in the cellular membrane, and those parts which are composed of it—the common integuments, membranes of the brain, pleura, peritonæum, periosteum, medullary membrane, tendons, aponeuroses, &c. or in the parenchymatous viscera, the liver, spleen, kidnies, secundines, the brain, and the rest of the nervous system, every one of which parts are destitute alike of muscular fibre, and of what is peculiar to it,—irritability.

302. As we find muscular irritability sometimes con-

founded with the contractility of the mucous web; so, on the other hand, some eminent men, particularly in modern times, have attributed it to the nervous energy.

Now, although we cannot deny the influence of the nerves upon the muscles, most strikingly shewn of late by the experiments of the celebrated Galvani and others, and although no muscular fibril, however minute, can be found absolutely destitute of nervous pulp, we are not on this account to assert, that irritability is not a power sui generis, as clearly different from the nervous energy as from contractility. For parts not muscular are not irritable, however abundantly they may be supplied with nerves, as the corium, the viscera; and the muscular texture alone exhibits the genuine phenomena of irritability. So that from the weight of these united arguments, to omit many others, it appears more just to assign these phenomena to the muscular fibre alone, than to ascribe them to the nerves, which are common to so many other parts, but do not in these excite the faintest sign of irritability. I say nothing of many weighty arguments derived from the facts, that no proportion exists between the degree of irritability and the number of nerves in any part; that one description of vital powers is often very energetic, while the other is languid in the same individual, according to national, morbid, or more especially to sexual variety.

303. The nerves exert their influence upon the muscles, as remote or exciting causes of their action, but by no means as the proximate or efficient, which is the inherent irritability of the muscles.

The passions, v. c. act upon the sensorium, this upon the nerves of the heart, so as to excite its irritability, which produces palpitation, and other anomalous motions.

The will acts upon the sensorium, this reacts upon the nerves of the arm, which excite muscular motion, as remote causes; but the proximate cause is the irritability of the muscles themselves.

304. With this distinction of the two causes of muscular motion, the result of those experiments, exactly correspond, which have been so frequently made by dividing or tying the nerves. Paralysis ensued, but irritability continued for a length of time afterwards.

There have been cases where one limb was motionless from paralysis, but retained its sensibility, while the other was insensible, but still capable of motion.

305. The true efficacy of the blood so copiously afforded to muscles, in promoting their action, is not clearly ascertained. In the Stenonian experiment, indeed, paralysis of the hind legs commonly follows the application of a ligature upon the abdominal aorta.

But after all, I am confirmed in the opinion formerly mentioned (125), that the action of voluntary muscles depends less than that of the heart, upon the afflux of blood to the moving fibres; and on the contrary, more than it upon the influence of the nerves which excite their irritability.

306. Besides these inherent powers common to all muscles, there are some peculiar and adventitious, arising from figure, situation, &c. answering their object with perfect accuracy.

307. From this circumstance, the muscles in general are divided into hollow and solid; the former, as we have seen, not directly subject to the will, but belonging more to the vital and natural functions, and consequently not to be considered at present, while we are speaking of the voluntary muscles, which belong to the order of animal functions.

308. Among the latter also, there is much variety. For, not to allude to difference of size, there is great variety in the disposition of their bands and fasciculi, and the direction of their fibres, in the proportion of the fleshy to the tendinous part, in their course, insertion, &c.

309. The greatest number are oblong, and their fleshy bellies terminate at each extremity in tendinous chords, inert, and destitute of irritability, and fixed to the bones, which they move in the manner of levers.

310. While a few muscles are destitute of tendons, such as the latissimus colli, an equally small number are not inserted into bones; such are the cremaster, as we generally find it, the azygos uvulæ, most of the muscles of the eye, &c.

311. The muscles endowed with those common (298 sq.) and peculiar (306 sq.) powers, are thus prepared to perform their actions, which also may be divided into common and peculiar.

312. A property common to all muscles, and the immediate consequence of their irritability, is to become shorter, more rigid, and generally unequal, and as it were, angular, during contraction.

To attempt, with J. and D. Bernoulli and other mathematical physicians, to reduce this diminution to a general admeasurement, is rendered impossible, among other causes, by the great difference between the hollow and solid muscles in this respect, and between the solid muscles themselves, v. c. between straight muscles (such as the intercostals) and sphincters.

313. The peculiar actions of muscles correspond with their peculiar powers, and consequently, vary so much as to be referrible to no general laws.

To cite one instance out of many, that action of certain muscles is peculiar and anomalous, which seldom occurs alone, but nearly always subsequently to the action of others, or in combination, or simultaneously with the action of some of a different order. Such is the action of the lumbricales, when, during rapid motions of the fingers, they follow the action of other muscles of the metacarpus and fore-arm; and of the lateral recti muscles of the eyes, either adducens of which seldom acts, unless simultaneously with the abducens of the other eye.

The commonly received law,—that a muscle during its contraction, draws the more moveable point of insertion to the more fixed, must be considered, as Winslow wisely remarks, perfectly relative, and subject to different limitations. Thus, for example, sometimes the one point, and sometimes the other, may be the more moveable: accordingly, as the united action of many different muscles may render the opposite more fixed; and, on the other hand, although the action of the flexors is generally stronger than that of the extensors, v. c. when the body is at rest, the fingers, &c. are a little bent, this does not so much depend upon the strength of the contraction of the flexors, as upon the voluntary relaxation of the extensors, for our own relief.

314. Every muscle has moreover a peculiar mechanism, adapted to the individual motions for which it is intended. Besides the determinate figure of each, many other kinds of assistance are afforded to their peculiar motions. The bursæ mucosæ, chiefly found among the muscles of the extremities; the annular ligaments, by which some are surrounded; the fat in which others are imbedded; the lymphatic vapour around each; and, above all, the conformation of the sceleton, chiefly in regard to apophyses,

condyles, and the articulations; nay, even whole bones, v. c. the patella, the pisiform of the carpus, and the sesamoid bones *, are destined to facilitate muscular action.

315. In this mode is compensated, or at least diminished, that inevitable loss of power, which necessarily takes place from the conformation and stature of the whole system, in which, from the acute angle at which some muscles are inserted, or the proximity of their insertion to the centre of motion, much of that power is lost, which would have existed, if their insertion had been more remote or at a more obtuse angle.

316. The human body, possessing 450 muscles, or even more, according to sexual or individual variety, is thus furnished with a double advantage,—with an extreme agility of motion in particular parts, and throughout the whole; and with a surprising degree of strength and endurance of labour. Both these are accomplished partly by the perfection of the muscles, which, like the perfection of ossification, takes place at manhood, and partly by habit and practice, the former of which in affording strength and agility to the muscles, is demonstrated in rope-dancers, leapers, runners, wrestlers, porters, savages, and the ancient nations.

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* Hence, of all animals which I have dissected, the mole is supplied with the most remarkable apparatus of sesamoid bones; its anterior palmated feet, with which it digs, have many of these bones, which greatly facilitate the action of the brachial muscles.

SECT. XX.

OF SLEEP.

317. THE faculties both of feeling and motion, possessed by the nervous system, whose history we have thus pursued, are so fatigued by their exertions in the day, that rest is necessary during the night to recruit them by means of sleep,—the image of death.

318. Sleep is a periodical function, by which the intercourse of the mind and body are suspended, and whose phenomena now to be traced, correspond very aptly with the supposition of a nervous fluid.

319. Besides other precursors of sleep, may be enumerated a gradually increasing dulness of the external senses, and a relaxation of most, especially of the long, voluntary muscles; a congestion of venous blood about the heart, and relief afforded by yawning to the uneasy sensation thus produced: lastly, a kind of slight delirium at the moment when sleep is all but present.

320. The phenomena of sleep, therefore, amount to this,—that the animal functions are suspended, and all the rest proceed more slowly and inactively. For the pulse is slower, the animal heat, cæteris paribus, diminished, perspiration more sparing, digestion imperfect, and nearly all the excretions (except that of the semen, which is indeed rather unusual) suppressed.

321. The remote causes of sleep are evident*. To omit narcotics, previous fatigue or watchfulness waste the animal powers, also habit, darkness, silence, rest, &c. which acquire their somniferous powers in some measure from habit; mild, continued, and uniform impressions upon certain senses; v. c. the murmur of a rivulet, or the view of a field of standing corn agitated by the wind, a previous meal, intense cold applied to the surface, and other modes of deriving blood from the head, as pediluvia, clysters, profuse hemorrhages.

322. These remote causes may induce the proximate cause, which, upon mature consideration, I think probably consists in a diminished flow of oxygenated (arterial) blood to the brain, for that fluid is of the highest importance, during the waking state, to the reaction of the sensoriun upon the senses and voluntary motions.

The influx of blood is diminished by its derivation from the brain and congestion in other parts; it is prevented, by the pressure of foreign matter upon the brain, whether from serous or purulent collections, from depression of fractured bones, &c.

This diminution or prevention of the flow of blood to the brain, causes a deficiency of water in the ventricles, and a collapse of them, upon which that acute and deep physiologist, David Hartley, on whom we formerly bestowed praise, explains the various phenomena of dreams.

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* Although the lethargic winter torpor of the Alpine marmot, the cricetus, and many other brute mammalia differs importantly from the sleep now spoken of, modern observations respecting this torpor have shewn, that, in their phenomena and remote causes, both correspond, and mutually elucidate each other.

Besides other phenomena, which accord with this explanation, one is very remarkable which I witnessed in a living person, already noticed,—that of the brain sinking whenever he was asleep, and swelling again with blood the moment he awoke.

323. The quantity of sleep depends much upon age, constitution, temperament, &c.; generally speaking, much sleep is the attendant of weakness, (as we find it in infants born prematurely and in superannuated persons,) and the very frequent source of fatuity and torpor.

124. We awake refreshed with sleep; and this return to life is attended by the same phenomena as the approach of sleep, by gaping, usually accompanied by stretching, some degree of dulness of the senses, &c.

325. The causes of waking correspond with those of sleeping. The proximate is the more free return of blood to the head. The remote are (besides the power of custom, which is in this respect very great) various stimuli, applied to the external or internal senses, either immediately, as the distension of the bladder, or mediately, as the imagination affecting the nervous system,—which is the case in dreaming.

326. Dreams are a wandering of the imagination, which recalls the ideas of objects formerly perceived, especially of objects of sight, and appears to employ itself with them.

It has been disputed whether dreams are natural during health. Some believe that they always occur during sleep, although they may escape our memory. Others conceive them the consequence only of derangement in some of the abdominal viscera. Very healthy adults have asserted, that they never dreamt.

They are generally confused and irregular, but occasionally discover extraordinary marks of reason.

The power of corporeal stimulants is very great in producing dreams; v. c. of the semen in producing lascivious trains of ideas, of excessive repletion in causing frightful appearances. We have one instance of a man, in whom any kind of dreams could be induced, if his friends, by gently addressing him, afforded the subject matter. This appears to be a preternatural state, between sleeping and waking; as does also the truly diseased case of sleep-walkers, and that affection which seizes them with what is termed magnetic ecstasy; which is, however, of a very different nature from the other.

Locke and others have regarded all dreams as a species of this mixed state.

SECT. XXI.

OF FOOD AND HUNGER.

327. As sleep repairs the loss of the animal powers, so food repairs that of the natural, and supplies fresh elementary particles in the room of those which are constantly wasting.

328. We are most effectually induced to procure and take food by various calls of nature, all tending to the same end; on one hand, by the intolerable torment of hunger and thirst; and on the other, by the equally powerful allurements of appetite.

329. Some ascribe *hunger* to an uneasiness arising in the stomach from being empty and unoccupied; others to the mutual friction of its rugæ; others not only to the stimulus of its fluids,—now secreted in abundance, of the saliva and gastric juice, but to an acrimony which they acquire unless food be taken in proper time. (A).

330. *Thirst* appears referrible both to a very unpleasant dryness of the fauces, and to the particular stimulus of acrid matters, especially of salts, taken by the mouth. It may be, therefore, the consequence of excessive absorption in the cavity of the mouth, such as occurs when the mother applies her infant to the breast, immediately after it has sucked; or, as happens not uncommonly, when

venesection or purging have been ordered. Violent passions frequently induce thirst. (B).

331. The necessity of obeying these stimuli, is more or less urgent according to age, constitution, and especially according to habit, and nothing can therefore be positively affirmed respecting their intensity; but thus much is certain, that an healthy adult, in whom all the calls of nature are felt in their usual force, cannot abstain from food a whole day without great prostration of strength, nor scarcely beyond eight days without danger to his life. (C).

332. Although thirst is a violent desire, drink appears not very necessary to life and health; for many warm blooded animals, mice, quails, parrots, &c. do not drink at all; and some individuals of the human species have lived in perfect health without tasting liquids.

333. It has been disputed whether our *food*, by which we satisfy these stimuli, is derived with the more advantage and the more consistently with nature, from the animal or vegetable kingdom.

334. Some contend that man is herbivorous, from the shape of his teeth, the length of his intestines, the difference between the structure of the small and large intestines, and the cells of the colon. Rousseau ingeniously urges the circumstance that woman is naturally uniparous and provided with two breasts. To these arguments it may be added, that some men have ruminated,—a power peculiar to herbivorous animals; that tame vegetable feeders are easily accustomed to animal food, whereas carnivorous animals, excepting the dog, can very seldom be brought to feed on vegetables.

The arguments of those who, with Helvetius, regard

man as carnivorous, are derived from the conformation of his stomach, the shortness of the cœcum, &c.

335. More careful observation, however, proves that man is not destined for either kind of food alone, but for both. His teeth, particularly the molares,* (D) and the peculiar structure of the intestines just alluded to, (E) hold a middle rank between the same parts in the feræ, and in herbivorous animals. The mode in which the condyles of the lower jaw are articulated with the temporal bones, demonstrate it in the most striking manner (F).

336. As the human race exists in more parts of the globe than any other kind of animal, had we been destined to subsist on either description of food alone, we should have been ill provided for; whereas man now inhabits some countries which afford either vegetable or animal food only.

337. Man is by far the most omnivorous of all animals, capable not only of feasting on luxurious combinations derived from each kingdom, but of subsisting with health and vigour on nearly one kind of the most simple food.

Thus, to mention a very few instances, many at present live on vegetables only, on the tubera of night-shade,

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* The opinion of Broussonet is singular. He thinks the human molares closely resemble the teeth of herbivorous animals; and at the same time regards the incisores and canini as allied to those of the carnivorous tribes: and, after comparing the number of the molares with that of the other teeth, concludes, that the quantity of vegetable food intended for man is to the quantity of animal food as 20 to 12. But on this calculation it follows, that infants, who have four molares only in each jaw, are destined to consume a larger portion of animal food than adults, as the proportion of molares to the other teeth is in them as 8 to 12.

on chesnuts, dates, &c. The first families of mankind, most probably, subsisted merely on fruits, corn, roots, and pulses.

Some tribes of Moors have no other food than gum seneka. The inhabitants of Kamtschatka, and of many other parts, live on fish alone.

The shepherds in the province of Caraccas in South America, on the banks of the Oronoko, and even the Morlachs in Europe, eat animal food.

Some barbarous nations devour raw animals. This cannot be denied to have been formerly the case with the Samojedes, the Esquimoes, and some tribes of South America.

Other nations are no less remarkable in their drink. The inhabitants of many intertropical islands, especially in the Pacific Ocean, can procure no sweet water, and drink nothing but the juice of cocoa-nuts.

Others take only sea-water.

Innumerable other facts of this kind clearly prove man to be omnivorous.

NOTES.

A.) If hunger arise from a sense of vacuity in the stomach, why should it be increased by the application of cold to the surface, the deglutition of cold liquids, &c.?

The explanation by friction of the rugæ is equally unsatisfactory; because the friction of these, if this does really occur, cannot be greater than the friction of the stomach against its contents after a meal, at which time hunger does not exist.

Nor can the presence of the gastric juice explain the matter; because no mental sensation can be shewn to arise in any other organ from the stimulus of its natural fluid; and I presume that this is the stimulus alluded to, because the mechanical stimulus from the bulk of the gastric juice, occurs equally from the presence of food, which does not excite hunger.

The supposition of an acrimony generated in the gastric fluid, &c. is, as a cause of hunger, absurd; it would be unfit for its purposes, and would be most likely to destroy rather than produce appetite.

Hunger has been attributed by some to a sympathy of the stomach with a general feeling of want in the system. But hunger is removed immediately that a due quantity of food is swallowed, long before the general system can have derived benefit from the meal. The circumstance giving rise to this opinion is the continuance of hunger, although food be taken in abundance, in cases of scirrhous pylorus and enlarged mesenteric glands. Here, it is urged, the hunger continues, because the body receives no nourishment. But, in scirrhus of the pylorus, vomiting soon follows the reception of food into the stomach, and therefore this organ is reduced to the condition in which it was previously, and the return of hunger is easily explicable. In diseases of the mesenteric glands, there is in fact no obstruction to the course of the chyle. Blumenbach always found them permeable (427), and the continued hunger appears rather a part of the diseased state of the chylopoietic viscera. Besides, many cases of imperfect nutrition, from various causes, occur without any increase of appetite.

If hunger arose from fatigue of the stomach, it should be greatest immediately after digestion, and gradually decrease; but it on the contrary increases.

Were irritation the cause, hunger should be greatest when the stomach is filled with food.

On the whole, hunger may perhaps be regarded as a sensation from the constriction of the interior of the stomach.

It is increased by cold drink, by cold air applied to the surface, by acids, bitters, and astringents; all which may be presumed to corrugate the stomach. It is diminished by heat and every thing which relaxes. Again, hunger ceases immediately that the stomach is filled, and thus all corrugation removed. Being, on this explanation, a sensation arising from a local state of the stomach, it will be affected not only by whatever affects this state, but by whatever affects also the sensibility to this state, and therefore be subject to the common laws of sensation. Thus, the state of the stomach remaining the same, hunger may diminish from the occurrence of other sensations which attract our attention more forcibly, by passions of the mind, &c.; as is exactly the case with all other sensations, even with those that are morbid. Under strong attention of the mind, either to pursuits of intellect or passion, to delightful or painful sensation, all other sensations cease to be felt, although really violent; and frequently, from being unattended to, do not recur. Passions, however, may affect hunger, not only by increasing or diminishing the sensibility to the constriction, but by increasing or decreasing the constriction,—the cause of the sensation.

(B.) As hunger appears to depend upon the local condition of the stomach, &c. so does thirst more evidently upon that of the fauces. Every consideration renders it probable that thirst is the sensation of the dryness of the parts in which it is seated. Whatever produces this dryness, either by diminishing the secretion of the mouth, &c. or by carrying off the fluid when secreted, produces thirst, and vice versa. Being a sensation, the same may be repeated in regard to it as was observed respecting hunger.

(C.) Instances of fasting for a much greater length of time may be found in authors, but these are extraordinary cases.

(D.) In carnivorous animals, the incisors are very large; and the molares generally of an irregular wedge form, those of the lower jaw closing in those of the upper like scissars, and being adapted for lacerating. In the herbivorous, the surface of the molares is horizontal or oblique, adapted for grinding.

(E.) As the food of herbivorous animals requires more preparation before it becomes the substance of the animal, the stomach is adapted to retain it for a length of time. The œsophagus opens nearer the right extremity of the stomach, and the pylorus nearer the left, so that a blind pouch is left on either side. In the carnivorous, the reverse is the case, and the stomach cylindrical, to favor the quick passage of the food. For the same reason, the intestines in the latter have generally shorter and fewer valvulæ conniventes; and, in some instances, no cœcum.

(F.) In animals which subsist on animal food, the condyles of the lower jaw are locked in an elongated glenoid cavity, and all rotatory motion is thus prevented, as motion upwards and downwards is sufficient for the laceration of the food. In vegetable feeders the joint is shallow, so that a horizontal motion is allowed for grinding the food.

SECT. XXII.

OF MASTICATION AND DEGLUTITION.

338. THE lower jaw is the chief organ of mastication, and is supplied as well as the upper with three orders of teeth, with incisors, generally* scalpriform, for the purpose of biting off small pieces, and not placed as in other mammalia, more or less horizontally in the lower jaw, but erect—one of the distinctive characters of the human race: with strong conical canine teeth, by which we divide hard substances, and which in man neither project beyond the rest, nor are placed alone, but lie closely and in regular order with the others :

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* I say generally : for omitting particular examples of their obtuseness, I may remark, that in the skulls of most mummies, I have found the crown of the teeth thick and obtuse. And since the more remarkable for this variety have resembled in their general figure and size the singular and never-to-be-mistaken physiognomy of the ancient Egyptians, observable in the idols, sarcophagi, and images of ancient Egypt, it is probable that this peculiar form of the teeth, whether owing to diet or whatever cause, was peculiar to the ancient Egyptians, so that it may be regarded as a natural mark or even character, by which the true ancient mummies may be distinguished from those of late formation.

I have written at large on this subject in the Philos. Trans. 1794, P. ii. p. 184.

With molares of various sizes, adapted for grinding, and differing from those of other mammalia, by possessing gibbous apices singularly obtuse.

339. The lower jaw is connected with the skull by a singular articulation, which holds a middle rank between arthrodia and ginglymus; and being supplied with two cartilaginous menisci of considerable strength, affords an easy motion in every direction. The digaster, assisted by the geniohyoidei and mylohyodei muscles, draws the lower jaw down, when we open the mouth.

The masseters and temporal chiefly raise it again when we bite off any thing, and are most powerfully contracted when we break hard substances.

Its lateral motions are accomplished by the internal and external pterygoid.

The latter can also draw it forwards.

340. Substances are retained in the mouth, and moved and brought under the action of the teeth by the buccinator and the tongue, which is very flexible and changeable in form.

341. During manducation, there occurs a flow of saliva which is a spumous fluid, consisting of a large portion of water united with a portion of albumen, and holding in solution a small quantity of phosphate of lime,—the source of the tartar of the teeth and salivary calculi. From being constantly applied to the tongue, it is insipid, although it contains some microcosmic salt, as well as muriatic and invariably oxalic acid. It is antiseptic and very resolvent.

342. The saliva flows from three orders of conglomerate glands, placed laterally and interiorally with respect to the lower jaw.

The principal are the *parotids*, which pour the saliva forth behind the middle molares of the upper jaw, through the Stenonian duct: the *submaxillary* through the Whartonian: the *sublingual*, the smallest, through the numerous Rivinian ducts.

343. The excretion of saliva, amounting, according to the arbitrary statement of Nuck, to a pound in twelve hours, is augmented by stimuli and by mechanical pressure, and, if the expression may be allowed, by emulsion.

The latter cause, greatly favoured by the situation of the parotids at the articulation of the jaws, occurs when we chew hard substances, which thus become softened.

The former arises from the presence of acrid matters, which are thus properly diluted; or from the imagination, as when the mouth waters during the desire for food.

344. The mucus of the labial and buccal glands and of the tongue, as well as the moisture which transudes from the soft parts of the mouth, is mixed with the saliva.

345. This mixture of fluids poured upon a substance which we are chewing, renders it not only a pultaceous and easily swallowed bolus, but likewise prepares it for further digestion and for assimilation.

346. The mechanism of deglutition, although very complicated, and performed by the union of many very different parts, comes to this:—the tongue being drawn towards its root, swelling and growing rigid, receives the bolus of food upon its dorsum, which is drawn into a hollow form.

The bolus is then rolled into the isthmus of the fauces, and caught with a curious and violent effort by the infundibulum of the pharynx, which is enlarged, and in some

measure comes forward to receive it. The three constrictores muscles of the pharynx, drive it into the œsophagus. These motions are all performed in very rapid succession, and require but a short space of time.

347. Nature has provided various contrivances for opening and securing this passage.

The important motion of the tongue is regulated by the os hyoides.

The smallest particle of food is prevented from entering the nostrils, or eustachian tubes, by means of the soft palate, which, as well as the uvula suspended from its arch, and whose use is not clearly understood, is extended by muscles of its own, and closes those openings.

The tongue protects the glottis, for the larynx at the moment of deglutition is drawn upwards and forwards, and in a manner concealed under the retracted root of the tongue, and applied to the latter in such a way, that the glottis being also constricted and protected by the epiglottis, is most securely defended from the entrance of foreign substances.

348. Deglutition is facilitated by the abundance of mucus which lubricates these parts, and which is afforded not only by the tongue (237), but by the numerous sinuses of the tonsils and the cryptæ of the pharynx.

349. The œsophagus, through which the food must pass previously to entering the stomach, is a fleshy canal, narrow and strong, mobile, dilatable, very sensible, and consisting of coats resembling, except in thickness, the coats of the other parts of the alimentary canal.

The external coat is muscular, and possesses longitudinal and transverse fibres.

The middle is tendinous, lax, more and more cellular

towards each of its surfaces, by which means it is connected with the two other coats.

The interior is lined, like all the alimentary tube, with an epithelium analogous to cuticle, and is lubricated with a very smooth mucus.

350. This canal receives the approaching draught or bolus of food, contracts upon it, propels it downwards, and, in the case of the bolus, stuffs it down, as it were, till it passes the diaphragm and enters the stomach.

SECT. XXIII.

OF DIGESTION.

351. THE stomach is the organ of digestion. It exists, what cannot be affirmed of other viscera, in all animals without exception; and, if the importance of parts may be estimated in this way, evidently holds the first rank among our organs.

352. The human stomach resembles a very large leathern bottle, is capable in the adult of containing three quarts and upwards of water, and has two openings.

The superior, called *cardia*, at which the œsophagus folded, and opening obliquely, expands into the stomach, is placed at the left side of its fundus.

The inferior, placed at the right and narrower part of the stomach, and called *pylorus*, descends somewhat into the cavity of the duodenum.

353. The situation of the stomach varies, accordingly as it is in a state of repletion or depletion. When empty, it is flaccid, and hangs into the cavity of the abdomen, its greater curvature inclining downwards, while the pylorus, being directed upwards, by doubling, forms an angle with the duodenum. When full, the anterior curvature is rolled forwards, so that the pylorus lies more in a line with the duodenum, while the cardia, on the contrary, is folded, as it were, into an angle and closed.

354. The stomach is composed of four principal coats, separated by the intervention of three others, which are merely cellular.

The *external* is common to nearly all the alimentary canal, and continuous with the omentum, as I shall presently mention.

Within this, and united to it by cellular membrane, lies the *muscular* coat, very remarkable, and the seat of the extraordinary irritability of the stomach.

It consists of strata of muscular fibres, commonly divided into three orders, one longitudinal and two circular, (straight and oblique) but running in so many directions that no exact account can be given of their course.

The third is the chief membrane. It is usually termed *nervous*, but improperly, as it consists of condensed mucous tela, more lax on its surfaces, which are united on one hand with the muscular, and on the other with the internal villous coat. It is firm and strong, and may be regarded as the basis of the stomach.

The interior, (besides the epithelium investing the whole alimentary canal) improperly called villous, is extremely soft and in a manner spongy, porous, and folded into innumerable rugæ, so that its surface is more extensive than that of the other coats ; it exhibits very small cells, somewhat similar to those larger cells which are so beautiful in the reticulum of ruminants. Its internal surface is covered with mucus, probably secreted in the muciparous crypts, which are very distinct about the pylorus.

355. The stomach is amply furnished with nerves from each nervous system (214), whence arises its great sensibility, by which it is so readily affected by all kinds of stimuli, whether external, as cold ; or internal, as food and its own fluids ; or mental ; whence also the great and

surprising sympathy between it and most functions of the system; to which are referrable the influence of all passions upon the stomach, and of the healthy condition of the stomach upon the tranquillity of the mind.

356. The abundance and utility of the blood-vessels of the stomach are no less remarkable. Its arteries ramifying infinitely upon the cellular membrane and glands, secrete the gastric juice, which appears to stream continually from the inner surface of the stomach.

357. The composition of this fluid is analogous to that of the saliva, equally antiseptic, very resolvent, and capable of again dissolving the milk which it has coagulated.

358. Digestion is performed principally by it. The food, when properly chewed and subacted by the saliva, is dissolved by the gastric fluid, and converted into the pultaceous chyme, so that many kinds of ingesta lose their specific qualities, and are defended from the usual chemical changes to which they are liable, such as putridity, rancidity, &c. and acquire fresh properties preparatory to chylification.

359. This important function is probably assisted by various accessory circumstances. Among them, some particularly mention the *peristaltic motion*, which, being constant and undulatory, agitates and subdues the pultaceous mass of food.

The existence of a true peristaltic motion in the stomach during health, is, however, not quite certain; the undulatory agitation of the stomach, if it occur, appears intended for the purpose of driving the thoroughly dissolved portions downwards, while those portions which are not completely subacted are repelled from the pylorus by the antiperistaltic motion.

360. The other assistants commonly enumerated, are the pressure on the stomach from the alternate motion of the abdomen, and the temperature maintained in the stomach, by the quantity of blood in the neighbouring viscera and blood-vessels, which at one time was supposed to be of such importance, that the word coction was synonimous with digestion.

361. To determine the time requisite for digestion, is evidently impossible, if we consider how it must vary according to the quality and quantity of the ingesta, the strength of the digestive powers, and the more or less perfect mastication previously.

During health, the stomach does not transmit the digestible parts of the food before they are converted into a pulp. The difference of food must therefore evidently cause a difference in the period necessary for digestion. It may, however, be stated generally, that the chyme passes the pylorus between three and six hours after our meals.

362. The *pylorus* is an annular limbus, consisting not like the other rugæ of the stomach, of merely the villous, but also of fibres derived from the nervous and muscular coats. All these united, form a conoidal opening at the termination of the stomach, projecting into the duodenum, as the uterus does into the vagina, and, as it were, embraced by it.

SECT. XXIV.

OF THE PANCREATIC JUICE.

363. THE chyme, after passing the pylorus, undergoes considerable changes in the duodenum,—a short but very remarkable portion of the intestines, before the nutrient chyle is separated. To this end, there are poured upon it various secreted fluids, the most important of which are the bile and pancreatic juice,.

364. Of these I shall treat separately, beginning with the pancreatic fluid, because it is closely allied both in nature and function, to the saliva and gastric juice already mentioned.

365. Although it is with difficulty procured pure from living and healthy animals, all observations made in regard to it, establish its resemblance to the saliva.

At the present day, it would scarcely be worth while to recount the erroneous hypotheses of F. Sylvius and his followers, R. De Graef, F. Schuyl, and others, respecting its supposed acrimony, long since ably refuted by the celebrated Pechlin, Swammerdam, and Brunner, unless they afforded a salutary admonition, how fatal the practice of medicine may become, if not founded on sound physiology.

366. The source of this fluid is similar to that of the saliva. It is the *pancreas*, by much the largest conglo-

merate gland in the system, and greatly analogous to the salivary glands in every part of its structure, even in the circumstance of its excretory ducts arising by small radicles, and uniting and forming one common duct, denominated, from its discoverer, Wirsüngian.

This duct penetrates the tunics of the duodenum, and supplies the cavity of the intestine with a constant stillicidium of pancreatic juice.

367. The excretion of this fluid is augmented by the same causes which affect the saliva; viz. by pressure and stimulus. By the former it is emulged, whenever the stomach, being in a state of repletion, is incumbent upon the pancreas.

By the latter, when fresh and crude chyme enters the duodenum, and the bile flows through the opening common to it and the pancreatic fluid.

368. Its use is to dissolve the chyme, especially if imperfectly digested in the stomach; and at all times, by its great abundance, to assimilate the chyme more to the nature of the fluids, and render it fitter for chylification.

SECT. XXV.

OF THE BILE.

369. THE bile is secreted by the liver, the most ponderous and large of all the viscera, especially in the fœtus, in which its size is inversely as the age. The importance of this organ is manifested, both by its immense supply of blood-vessels, and their extraordinary distribution, as well as by its universal existence. It is not less common to all red-blooded animals than the heart itself.

370. The substance of the liver is peculiar, easily distinguished at first sight from that of other viscera; consisting of a parenchyma well known in colour, and delicate in texture; supplied with numerous nerves and lymphatics (most remarkable on the surface); with biliferous ducts; and blood-vessels from which the latter originate, both very numerous, and in some instances very large, but of different descriptions, as I shall state particularly.

371. The first blood-vessel to be noticed is the *vena portæ*, whose dissimilarity from other veins, both in its nature and course, were formerly hinted at. Its trunk is formed from the combination of most of the visceral veins belonging to the abdomen, is supported by a cellular sheath, called the capsule of Glisson, and on entering the liver, is divided into br nches, which are subdivided

more and more as it penetrates the substance of the organ, till they become extremely minute, and spread over every part. On this account, Galen compared this system to a tree, whose roots were dispersed in the abdomen, and its branches fixed in the liver.

372. The other kind of blood-vessels belonging to the liver, are branches of the *hepatic artery*, which arises from the cœliac, is much inferior to the vena portæ in size and the number of its divisions, but spreads by very minute ramifications throughout the substance of the liver.

373. The extreme divisions of these two vessels terminate in true veins, which unite into large venous trunks running to the *vena cava inferior*.

374. They are inconceivably minute, and collected into very small glomerules, which deceived Malpighi into the belief that they were glandular acini, hexagonal, hollow, and secretory.

375. From these glomerules arise the *pori biliarii*, very delicate ducts, secreting the bile from the blood, and discharging it from the liver, through the common hepatic duct, which is formed from their union.

376. It has been disputed whether the bile is produced from arterial or venous blood.

Although the former opinion is countenanced by the analogy of the other secretions which depend upon arterial blood, nevertheless more accurate investigation proves that the greater part, if not the whole of the biliary secretion, is venous.

With respect to arguments derived from analogy, the vena portæ, resembling arteries in its distribution, may likewise bear a resemblance to them in function.

Besides, the liver is but analogous to the lungs, in

which the great pulmonary vessels conspire to the function of the lungs, while the bronchial arteries are intended for their nourishment; and, if I am not greatly mistaken, the use of the hepatic artery is similar. I would, however, by no means completely deny its importance in the secretion of bile, but I must regard it as inconsiderable, adventitious, and not well established (A).

377. The bile flows slowly and regularly along the hepatic duct. The greater portion runs constantly through the ductus communis choledochus into the duodenum, but some passes from the hepatic duct into the cystic, and is received into the gall-bladder, where it remains for a short period, and acquires the name of cystic bile.*

378. The gall-bladder is an oblong sac, nearly pyriform, adhering to the concave surface of the liver, and consisting of three coats.

The exterior, completely covering it, derived from the peritonœum.

The middle, called nervous, as in the stomach, intestines, and urinary bladder, the source of its firmness and tone.

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* In cows and other brutes there are peculiar hepato-cystic ducts, which convey the bile directly from the liver to the gall bladder. Observ. Anat. coll. privati Amstel. p. 1. Ams. 1667. 12. p. 16. sig. 7. Also, Perrault's Essays de Physique, t. i. p. 339. tab. ii.

Some have inconsiderately allowed them also in the human subject; v. c, De Haen, in his Ratio Med. Cont. P. 11. p. 46. et seq. tab. x. fig. 1.

Also, Pitschell, in his Anat. und Chirurg. Anmerk. Dresd. 1784. 8. tab. i. R. Forsten's Quæst. Select. Physiolog. Lugd. Batav. 1774. 4. p. 22.

The interior, somewhat like the inner coat of the stomach, containing a net-work of innumerable blood-vessels, abundant in mucous glands, and marked by rugæ, which occasionally exhibit a beautifully cancellated reticulum.

379. Its cervix is conical, terminates in the cystic duct, is tortuous, and contains a few falciform valves.

380. The bile which has passed into the gall-bladder is retained until, from the reclined or supine posture of the body, it flows down from it spontaneously, or is squeezed out by the pressure of the neighbouring jejunum or ileum, or of the colon when distended by fæces.

The pressure of stimuli in the duodenum may drive the bile in that direction.

The great contractibility of the gall-bladder, proved by opening living animals and by pathological phenomena, (although it has not true irritability) probably assists the discharge of bile, especially when this fluid has, by retention, become very stimulating.

381. For the cystic bile, although very analogous to the hepatic, becomes more concentrated, viscid, and bitter, by stagnation in the gall-bladder; the cause of which is, in all probability, the absorption of its more watery parts by the lymphatic vessels.

382. Our attention must now be turned to the bile itself,—a very important fluid, respecting the nature and use of which there has been for these thirty years more controversy than respecting any other fluid. The cystic bile being more perfect and better calculated for examination, will supply our observations.

383. Bile taken from a fresh adult subject, is viscid, of a brownish green color, inodorous, and, if compared with that of brutes, scarcely bitter.

384. Its constituent parts, obtained by chemical analysis, are, besides a large proportion of water, albumen, resin, soda, united partly with phosphoric, sulphurous, and muriatic acid, a small portion of phosphate of lime and iron, and variable quantities of a remarkable and peculiar yellow matter.

385. The composition of the bile varies greatly both from the proportion particularly of the albuminous and resinous parts differing under different circumstances, and also from the addition, during morbid states, to the biliary secretion, of other constituents, especially of adipocerous substances, which give origin to most biliary calculi; for these consist either of it alone, or of it combined with the yellow substance just mentioned (B).

386. The nature of the bile is not saponaceous and capable of effecting a combination between water and oils, as Boerhaave supposed, but which opinion the experiments of Schroder, who was formerly of this university, both confirmed and extended by other physiologists, have disproved. It even decomposes a combination of those substances.

387. The important and various use of the bile in chylification is self-evident.

In the first place, it precipitates the fæces, and separates the milky chyle from the mixed and equable pultaceous chyme propelled from the stomach into the duodenum, and diluted by the pancreatic juice.

It separates itself into two portions, the one serous, the other resinous. The latter combines with the fæces, tinges them, and is discharged with them; the former is probably mixed with the chyle, and carried back to the blood.

The bile may act as a stimulus to the peristaltic motion of the intestines. I shall omit other less probable uses

assigned to the bile, viz. of exciting hunger by regurgitating into the stomach,—a circumstance which I think can scarcely happen during health.

NOTES.

(A) Two instances have occurred in London, of the vena portæ running not to the liver, but immediately to the vena cava inferior. The bile must have been secreted entirely from the blood of the hepatic artery. One of these is described by Mr. Abernethy, and the other will shortly be made known.

(B) Berzelius (Animal Chemistry, 65,) states, that bile contains alkali and salts in the same proportion as the blood; that no resin exists in it, but "a peculiar matter, of a bitter and afterwards somewhat sweet taste, which possesses characters in common with the fibrin, the colouring matter, and the albumen of the blood." This forms with an excess of acid, a perfectly resinous precipitate. What has been considered as albumen in the bile, Berzelius regards as the mucus of the gall-bladder.

SECT. XXVI.

OF THE FUNCTION OF THE SPLEEN.

388. THE *Spleen* lies to the left side of the liver, and with it has considerable vascular communications; its figure is oblong; it applies itself to the contiguous viscera, and is liable to great varieties in point of form, number, &c.

389. Its colour is livid, its texture singular, soft, easily lacerated, and therefore surrounded by two membranes, the interior of which is proper to the spleen, and the exterior is derived from the omentum.

390. The situation and size of the spleen are no less various than its figure, and depend upon the degree of repletion of the stomach: for when the stomach is empty and lax, the spleen is turgid, and vice versa. It undergoes a continual but gentle and equable motion, dependent upon respiration, under the chief instrument of which —the diaphragm, it is immediately situated.

391. Its texture was formerly supposed to be cellular, and compared to the corpora cavernosa of the penis. This opinion was proved to be erroneous by more careful examination of the human spleen, which consists entirely of blood vessels, of enormous size in proportion to the bulk of the organ. They are in fact more considerable than in any other part of the body.

392. The experiments of Wintringham demonstrate the great tenuity and strength of the coats of the splenic artery. It is divided into an infinite number of twigs, the terminations of which resemble pulpy penicilli, and give rise to the splenic veins, which unite into large, loose, and easily dilatable trunks.

393. This immense congeries of blood vessels is connected and supported by a sparing cellular parenchyma, from which the absorbents arise. The trunks of these run along the lower surface of the spleen, between the two coats just described.

394. This loose structure of the spleen, easily becoming distended with blood, admirably confirms what we formerly remarked respecting the turgor of this organ, (390). The congestion and slow return of the splenic blood, if the nature of the neighbouring organs is also taken into consideration, illustrates its peculiar properties, which may throw some light upon the function of this enigmatical viscus,—the source of so much controversy.

395. The splenic blood is very fluid, coagulates and separates the serum from the crassamentum with great difficulty, is of a livid dark colour, like the blood of the fœtus. These circumstances clearly demonstrate the abundance of carbonaceous matter; which is likewise proved indisputably by an easy experiment. Whenever I have exposed sections of a recent spleen to oxygen gas, they became of a very bright red, while the air losing its oxygen, became impregnated with carbon.

396. But since the spleen is the only organ of that description quite destitute of an excretory duct, excepting its veins, which run ultimately to the liver, its function is probably subservient to that of the liver. This opinion is strengthened by the observation, that in animals de-

prived of their spleen, an experiment frequently made from the most remote period, the cystic bile is found pale and inert.

397. At least twenty hypotheses have been framed respecting the use of the spleen. Two more have been lately advanced; both supposing a connection between the spleen and stomach, but the one regarding the spleen as a diverticulum to the blood destined to form the gastric juice; the other, supported by excellent arguments and experiments, making the spleen receive a great portion of our drink from the cardiac extremity of the stomach, so that these may pass through a short way, hitherto unknown, from the stomach to the spleen, and thus into the mass of blood. The latter hypothesis, if a few objections were removed,* would be much the most plausible of any hitherto constructed (A).

NOTE.

(A) Mr. Home, having passed a ligature around the pyloric extremity of the stomach of a dog, injected into it a solution of rhubarb; and, on killing the animal some hours afterwards, none of the absorbents of the stomach were found distended, nor could any trace of rhubarb be detected in the liver, but evident traces existed in the spleen and the urine.

* The size of the spleen in those warm blooded animals which never drink, or in bisulcous animals, whose spleen adheres to the ruminant stomach, receiving the crude food only, but never the drink, which is prevented from entering it, by the well-known mechanism of a semicanal, running from the œsophagus to the omasum.

SECT. XXVII.

OF THE FUNCTION OF THE OMENTUM.

398. THE omentum gastrocolicum, or magnum, (to distinguish it from the parvum, or hepato-gastricum), is a peculiar process of peritonœum, arising immediately from the peritonœum of the stomach.

399. Although there are innumerable continuations of the penitonœum in the abdomen, and every abdominal viscus is so covered by it, that, on opening the abdomen, nothing is found destitute of that membrane; this covering, nevertheless, is afforded in different ways, which may be reduced to classes.

Over some the peritonœum is merely extended, or it affords to them only a partial covering, as with respect to the kidneys, rectum, urinary bladder, and in some measure to the pancreas and gall-bladder.

To some which project into the cavity of the abdomen, although adhering to its parietes, it affords a covering for the greater part of their surface; v. c. to the liver, spleen, stomach, uterus, and the testes of the very young fœtus.

The intestinal tube, with the exception of the rectum, projects so much into the cavity of the abdomen, that it is, as it were, suspended in loose processes of the peritonœum, called mesentery and mesocolon: the broad ligaments of the uterus are similar to these.

400. The longest and most remarkable process of peri-

tonæum, is the *omentum*,—a large, empty, delicate, sac, hanging from the large curvature of the stomach, extended over the greater part of the small intestines, applying itself closely to their convolutions, and in some measure insinuating itself into their interstices.

401. Besides the blood vessels seen upon the omentum, it is marked by fatty striæ or bands, every where reticulated (whence the common appellation of this membrane), which in lusty persons increase occasionally to a large and even dangerous size, and by means of which the whole omentum is lubricated by an adipose halitus.

402. On the latter circumstance depends the use commonly ascribed to the omentum, of lubricating the intestines, and assisting their continual movements: this also appears the use of those analogous small bursæ which are found in such numbers about the rectum and colon.* The omentum also prevents the adhesion of the intestines to the peritonæum, and the consequent impediment to the functions of the primæ viæ.

403. There is another two-fold office attributed with great probability to the omentum; viz. that of facilitating the dilatation of the viscera, to which it is contiguous, and of acting as a diverticulum to their blood, during their state of vacuity.

404. If we reflect on the singular structure of the omentum parvum, or hepato-gastricum especially, we may be inclined to believe that there is another office attaching to it, unknown at present, and discoverable by comparative anatomy.

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* I have lately seen similar appendices on the peritonæal covering of an uterus unimpregnated, but which had formerly been pregnant.

SECT. XXVIII.

OF THE FUNCTION OF THE INTESTINES.

405. THE intestinal tube, over which the omentum is extended, and which receives the chyme to elaborate it farther, and separate the chyle from the fæces, is divided into two principal portions,—the small and large intestines, of whose functions I shall speak separately.

406. The small intestines are again divided into three: the duodenum, jejunum, and ileum.

The first is named from its usual length.

The second from generally appearing collapsed and empty.

The third from its convolutions: it is the longest of the three, fuller, and, as it were, inflated, and sometimes resembling the large intestines by the appearance of bullæ.

407. The coats of the small intestines correspond with those of the stomach.

The *external* is derived from the mesentery.

The *muscular* consists of two orders of fibres: the one longitudinal, interrupted, external, and found especially about the part opposite the mesentery; the other, annular and falciform, possessing the power of narrowing the canal, while the former shortens it. Upon both depend

the very great and permanent irritability of the intestines, formerly mentioned (300).

The *nervous* coat is a condensed cellular membrane, easily reduced by handling, or more particularly by inflation, into a spumous tela; in it the vessels run to the mesentery in a beautifully arborescent form; the intestines, no less than the stomach, are indebted to it for their tenacity and strength.

The interior, lined by its delicate epithelium, and deserving the name of villous in the small intestines more than in any other part of the canal, forms, in conjunction with the inner surface of the former coat, here and there, undulated ridges and rugous plicæ, which, in dried and inflated intestines, resemble the edge of a scythe, and are termed the valvulæ conniventes Kerkringhianæ.

408. The villi, which are innumerable upon the inner surface of the intestines, and whose beautiful and minute vascular structure was first carefully investigated, though described with exaggeration, by Lieberkühn*, may be, perhaps, compared, while destitute of chyle, to little loose pendulous bags, internally soft and spongy; but when distended with chyle, they have the appearance of a morel.

409. The base of the intestines is surrounded by innumerable glandular follicles, adhering chiefly to the nervous coat, and opening into the intestinal canal by a very small orifice, through which they discharge the mucus, lining the whole tract of the intestines.

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* He estimated their number, in the small intestines of an adult, to be about 500,000.

These are distinguished into three orders. The Brunerian, largest, distinct, found in most abundance in that part of the duodenum which is contiguous to the pylorus. The Peyerian, smaller, aggregated, found chiefly at the termination of the small intestines, about the valve of the colon. Lastly, the Lieberkühnian, the smallest, said to be distributed in the proportion of about eight to each villus. The two former orders are so irregular, that I am inclined to consider the view given of them in the plates alluded to, as morbid*; for I have more than once been unable to discover the slightest trace of fungous papillæ with a single pore, in the intestines of healthy adults; while, on the contrary, in aphthous† subjects, I have found nearly the whole intestinal tube beset with them in infinite numbers, both solitary and aggregated.

410. As the gastric juice is poured into the stomach, so an enteric or intestinal fluid is poured into the small intestines, demonstrated, among other ways, by the common experiment, first, I believe, instituted by Pechlin. It is probably of a nature similar to the gastric liquor, but an accurate investigation of it is a physiological desideratum. I can say nothing respecting its quantity, but the estimation of Haller is certainly exaggerated,—at eight pounds in the twenty-four hours.

411. The intestines agree with the stomach in this particular, that they have a similar, and indeed a more certain,

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* The celebrated Rudolph thinks differently.

† These intestinal aphthæ exactly resemble those tubercles, which Shelton (whom we shall presently quote) exhibits as small ampullæ full of chyle.

or, at least, a more lively, peristaltic action, which occurs principally when the chymous pulp enters them. This it agitates by an undulatory constriction of different parts of the alimentary canal, and propels from the duodenum towards the large intestines. Although the existence of an antiperistaltic motion, causing a retrograde course to their contents, cannot be disproved, it is in health much weaker, and less common and important than the former.

412. By these moving powers and by these solvents which are afforded by means of secretion, the chyme undergoes remarkable changes. In the jejunum it becomes a more liquid pulp, equally mixed, of a grey colour, and rather accidulous odour: in the ileum, it begins to separate into two parts,—into the fæces, of a pale, yellowish, brown colour*, and nauseous smell; and the genuine chyle

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* I have formerly (387) remarked that the bilious colour of the fæces arose from the excrementitious part of the bile. In the jejunum, the bile being undecomposed and mixed with the equable pulp in the intestines, and consequently diffused and diluted, cannot exhibit its true colour. But after its separation into two parts, the excrementitious portion, mixed with the precipitated fæces, and, as it were, again concentrated, now discovers its original colour, and imparts it to the fæces.

C. F. Wolff (in the Act. Petropolit. 1779. P. ii. p. 245,) entertains a different opinion in regard to the cause of the bilious colour of the fæces contained in the ileum. He conceives that an addition of bile occurs near the extremity of the jejunum, by exhaling from the gall bladder and penetrating this part of the intestine and its contents.

This bile differing, perhaps, in its nature, from the bile of the choledochus, and not being mixed with the fæces as the latter is with the chyme, retains its colour through all the remaining tract of the intestines and continues pure bile. But, besides our being able easily

swimming upon the former, extracted from the chyme, separated by the bile from the fæces, and destined for absorption by the lacteal vessels, as we shall find in the next section. At present, we shall enquire what course is taken by the fæces.

413. These, after becoming more and more inspissated in their long course through the ileum, have to overcome the valve of the colon, and pass into the large intestines. To facilitate this, the extremity of the ileum is lubricated very abundantly by mucus.

414. The *valve of the colon*, or, as it may deservedly be termed after its discoverer, the valve of Fallopius*,

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to explain why this colour is not observable before the decomposition of the chyme and bile, it is extremely doubtful whether, during health, any exhalation can occur from the gall bladder, and penetrate the intestine. For in subjects recent, and even scarcely cold, the intestines are but slightly tinctured with bile, although they are dyed with it very extensively, after a lapse of some hours or days, i. e. after the coats of the gall bladder have lost their tone, and become incapable of preventing the transudation of their contents.

* The various opinions respecting the discoverer of this remarkable valve are well known. Haller's Elements, t. viii. P. I. page 142, may be consulted on this point. In the mean time, I am certain, that long before the period at which its discovery is in general dated, it was accurately known by that immortal anatomist Gabr. Fallopius. In our university library there is a manuscript of Fallopius, containing, among other things, his anatomy of the monkey, the structure and use of the valve of the colon in which, he explains, in a public demonstration, given at Padua, Feb. 2, 1553, in the following words: " The use of the cœcum in the monkey, is to prevent the regurgitation of the food during progression on all ours. This is proved by the circumstance of water thrown into

is a short process or continuation of that part of the ileum which penetrates into the cavity of the large intestine surrounding the former. Its external lips, while a neighbouring fold of the large intestine at the same time projects considerably, are constituted not like other similar folds, merely of the interior and nervous coats, but of fibres from the muscular coat. Hence it performs the double office of preventing too great a quantity of fæces from passing from the small into the large intestines, and of preventing regurgitation from the latter.

415. The large intestines, divided like the small into three parts, commence by the cœcum (which has a vermiform process, whose use in man is unknown) and afford a very ample receptacle, in which the fæces may be collected and retained till the period of their discharge arrives.

416. They exceed the small intestines in thickness and strength, as well as in capacity. The muscular coat has this peculiarity,—that its longitudinal fibres, excepting at the extremity of the rectum, are collected into three bands, called ligaments of the colon; and the intestine itself is divided into a kind of prominent cells. The inner coat is not so beautifully flocculent as in the small intestines, but more similar to what is observed in the stomach.

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the rectum, reaching the cœcum, but not passing beyond the large intestines. But, if thrown in from above, it passes this part. The reason is this,—at the insertion of the ileum are two folds, which, during inflation and repletion, are compressed, as occurs in the heart, and prevent retrogression; wherefore, in man, clysters cannot pass and be rejected through the mouth, unless under a weak and diseased state of the intestines."

417. Their peristaltic motion is much fainter than that of the small intestines. On the other hand, they experience to a greater degree the pressure of the abdominal parietes, to which the whole length of the colon is contiguous.

418. They gently propel the fæces into the rectum, which thus becomes internally stimulated to discharge its contents. This is facilitated by the absence of transverse rugæ, and by the great quantity of mucus at the extremity of the bowels.

419. The discharge of fæces is principally effected by the pressure of the abdomen downwards, overcoming the resistance of the os coccygis and both sphincters. The inner sphincter is a remarkable bundle of circular fibres; the external, a truly cutaneous muscle. After the excretion, the effort of the abdomen having ceased, the levator ani retracts the intestine, which is again closed by its sphincter.

SECT. XXIX.

OF THE FUNCTION OF THE ABSORBENT VESSELS.

420. THE chyle which we left in the ileum just separated from the fæces, evidently must be a mixture of different fluids. The proportion derived from the secretions,—the saliva, bile, the gastric, pancreatic, and enteric fluids, surpasses, without the least doubt, that which is derived from the aliment, although it cannot be accurately ascertained. Hence must be obtained the solution of the problem,—how injesta of such various kinds can be converted into the chyle—an equable, homogeneous fluid, of an animal nature.

421. The course of the chyle from the intestines to the blood, is through a part of the absorbent system, which I have hitherto only hinted at, but shall now speak of particularly. It is divided into four parts,—lacteal and lymphatic vessels, conglobate glands, and the thoracic duct. Each of these will now fall under consideration.

422. It is certain that the lacteals originate among the villi of the internal coat of the intestines; but whether they are an immediate continuation of these villi, or merely connected with them by a cellular medium, admits a question. I myself have never been able to trace their immediatc connexions; but they appear to arise here and there in the coats of the intestines, by a conspicuous

trunk, and we may conjecture that they take up the chyle, from the cellular structure into which it is first drawn by the villi. This I have in fact observed repeatedly in puppies, after making them swallow a solution of indigo, according to the celebrated experiment of Lister, an hour or two before opening them alive.

423. The trunks just mentioned run some inches along the surface of the intestines, under the external coat, sometimes meandering in an angular course, before they reach the mesentery.

424. In their course through the mesentery, they run into the mesenteric glands, of which there are two series. The one, nearer the intestines, dispersed, and resembling beans in their shape; the other, nearer the receptaculum chyli, large, and more aggregated.

425. Both appear nothing more than closely-compacted collections of lacteals, interwoven with innumerable blood-vessels, and retarding the course of the chyle; to the end, perhaps, that it may be more intimately and perfectly assimilated to an animal nature, previously to its entrance into the thoracic duct and its mixture with the blood.

426. It has been enquired whether lacteals exist also in the large intestines, and their existence has been contended for from the effects of particular injections, nutrient, inebriating, &c. and also by the circumstance that the fæces, if retained for any length of time, become hard and dry. Although these arguments do not demonstrate the absorption of genuine chyle below the valve of Fallopius, nevertheless it is rendered probable by the visible existence of an abundance of lymphatics in the large intestines, having the same structure and function with the lacteals; for these absorb lymph during the absence of chyle from the intestines.

But the very different structure of the internal coat of the large intestines from that of the villous coat of the small, strongly argues that they are not naturally intended to absorb chyle.

427. There is another question more important and difficult of solution,—whether all the chyle absorbed from the small intestines, passes through the thoracic duct, or whether some enters the blood by other more secret passages? The latter opinion rests upon very unstable arguments. Thus the assertion of Ruysch, that the mesenteric glands become, in advanced life, indurated and unfit for continuing their functions, was long since disproved; and affections of these glands, swellings, &c. are improperly called obstructions, as the glands remain pervious, readily allowing a passage to quicksilver. The well-known phenomenon of tepid water infused after death into the mesenteric veins, passing into the cavity of the intestines, has little weight with me in regard to a function which occurs during life; and much less weight can be allowed to the bifurcated brass tube invented by Lieberkühn to prove the existence of these passages. The assertion, that chyle has been seen in the mesenteric veins, requires farther investigation and proof; so that I cannot believe that they carry any thing more than blood, very carbonized, and destined for the formation of bile*.

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* There is a beautiful experiment, which seems, at first sight, to favor the existence of these passages, and for which I am indebted to the eminent L. M. A. Caldani. In a lamb or kid, after hearty feeding, a ligature is placed upon the vein corresponding with our left subclavian, and another, particularly tight, upon the mesentery, at its origin near the lumbar vertebræ. The lacteals and lymphatics, between the ligatures, become very evident; and like-

428. The ultimate trunks of the lacteals, arising, like the other lymphatics, from the combination of a great number of small twigs, unite into the receptaculum or cisterna chyli,—the appellation by which the lower and larger part of the thoracic or Pecquetian duct is distinguished.

429. This duct is a membranous canal, slender, strong, more or less tortuous, subject to great varieties in its course and division, destitute of muscular fibre and nerves, and possessing here and there valves. At about the lowest cervical vertebra, after passing the subclavian vein, it again turns back and is inserted into it, being furnished with a valve at the point of insertion.

430. The motion of the chyle throughout its course is to be ascribed to the contractility of its containing vessels, to their valves, and the vis-a-tergo.

431. The use of the valve placed at the opening of the thoracic duct, is probably not so much to prevent the

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wise the lymphatics ascending from the hind legs. At first, the lacteals between the intestines and constricted mesentery swell, but they soon subside and disappear.

But this singular phenomenon appears to me not owing so much to any clandestine passages for the chyle, as to a retrograde motion of the chyle into the intestines; the valves, under these circumstances, not offering sufficient opposition. Vide B. V. Gottl. Schreger's Fragmenta Anatomica et Physiologica. Fasc. 1. Lips. 1791. 4. p. 26.

Hor. Caldani, in his Riflessioni sopra alcuni punti di un nuovo sistema de' vasi assorbenti et Patav. 1792. 8. p. 58.

And his uncle, commended above, L. M. A. Caldani, in his Commentary to be found in the Memoire lette nell' Accad. di Padova. 1804. 4.

influx of blood, as to modify the entrance of the chyle into the vein,—to cause it to enter by drops.

By this contrivance, such a portion of fresh chyle cannot have access to the blood as would stimulate the cavities of the heart too violently, and be imperfectly and difficultly assimilated; for fresh chyle consists of very heterogeneous elements, brought not only from the primæ viæ by the lacteals, but from every part of the body by the lymphatics.

432. These *lymphatics*, which constitute the third part of the absorbent system, and resemble the lacteals in structure and function, are much more, and, indeed, universally, diffused. They arise principally from the mucous web, which we called the grand bond of connection between the sanguiferous and absorbing system (27); but in great numbers likewise from the external common integuments, from the fauces, and œsophagus (330), the pleura and peritonæum, and from the thoracic and abdominal viscera.

433. Their origin is similar to that of the lacteals in the intestines, so that the radicle of each lymphatic absorbs the fluid from the neighbouring cellular membrane, as from its territory, and propels it onwards.

434. The lymphatics have double valves, set more or less thickly in different parts; they all enter conglobate glands; those which are contiguous to each other, anastomose here and there; and those found on the surface of certain viscera, as the lungs, liver, &c. form a most beautiful network.

435. Besides other assistances to their functions, evident from what has already been said, no inconsiderable assistance is derived from the combination of great strength with thinness in their coats, by which

they are enabled to support a heavy column of quicksilver. In the limbs, especially, the motion of the muscles pressing them on every side, is highly useful in increasing their power.

436. But their principal action, by which they take up fluids more or less rapidly, eagerly absorbing some, and absolutely rejecting others, depends upon the peculiar modification of their vitality, and is ascribed by the very acute Burgmans to a certain *vita propria*.

437. The far greater part of these lymphatics terminate in the thoracic duct; except, however, those of the right arm, the right side of the neck, the right lung, and the right portion of the diaphragm and liver, which terminate in the subclavian vein of the same side.

438. From the universal existence of the lymphatics, and especially from the great numbers on the surface capable of absorbing fluids from without, the heterogeneous nature of the lymph must be obvious; and this is further proved by accurately examining it in different parts of a subject; v. c. that contained in the hepatic or splenic lymphatics is perfectly different from that in the uterine.

439. I will enumerate the principal fluids which are continually absorbed during health, to say nothing of many different kinds of substances taken up during disease. There is, besides the chyle separated from the fæces in the small intestines, the halitus of the cavities properly so called, especially that of the fauces and the mucous web, the fat, the more watery of those secreted fluids which are retained for some time in their ducts, v. c. of the milk, semen, bile, and not a small portion of the fluids in contact with the surface.

440. The solids, after performing their purpose in the economy, insensibly melt away and are absorbed, as is proved by the absorption of the greater part of the thymus gland during infancy, of the roots of the first teeth, and of the alveoli after the second teeth have fallen out. The constant change of the whole osseous system, arising from the insensible renovation of the bony matter, of which I have treated elsewhere professedly, may also be adduced.

441. It is therefore evident, that since so great a variety of matter is absorbed, and at the same time nothing crude or improper allowed to enter the blood, there is a necessity for some peculiar medium for previously subacting and assimilating the various substances.

442. It appears to be the chief office of the conglobate glands, which constitute the last part of the absorbent system, to prevent the ill effects, upon the heart, of the improper admixture of crude fluid * with the blood, by assimilating more and more to an animal nature the various fluids, particularly those absorbed by the skin, and

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* If we consider the winding course which nature has provided for the purpose of changing and assimilating the absorbed fluids previously to their admixture with the blood; and, on the other hand, the dreadful symptoms, such as palpitation, convulsions, &c. which ensue upon the artificial infusion of a minute portion of any mild fluid into the blood, we shall be thoroughly convinced that no absorption of heterogeneous fluid takes place by the veins, excepting that of the blood itself (v. c. in the erection of some parts, in the placenta. &c.), and that those absorptions which Haller endeavours to prove to be accomplished by the veins, do really take place by means of the lymphatic system. de c. h. Funct. V. i. p. 281 & seq.

by retarding their motion; perhaps also by superadding to them some fresh secreted fluid.

443. As to the rest of those glands, dispersed generally through the body, and aggregated here and there, as in the groin and axillæ, they are perfectly similar to those found in the mesentery, consisting, like them, in a great measure, of convoluted absorbent vessels, supplied with an immense number of blood vessels, and liable to the same diseases.

SECT. XXX.

OF SANGUIFICATION.

444. THERE is no occasion to remark that I employ the term Sanguification to denote the assimilation of the chyle to the blood, and the reparation, by means of the former, of the loss sustained by the latter, in repairing the losses of the different parts.

445. The division of all our fluids into three classes (45), crude, sanguineous and secreted, turns upon this; that the middle class contains the stream of the vital fluid itself, from which the numerous secreted fluids are perpetually withdrawn, and to which, on the other hand, there is a constant afflux of chyle and lymph from the absorbent system.

446. But since the blood is a peculiar fluid, *sui generis*, without its fellow in nature, various assistances and media are evidently requisite to subact and assimilate the heterogeneous and foreign fluids which pass to it from the thoracic duct.

447. This is, in the first place, especially in the mesenteric and conglobate glands, accomplished by those windings, mentioned formerly, of the lacteals and lymphatics, which are, at the same time, gradually more impregnated, as it were, with an animal nature.

448. We must also take into consideration, that a great part of the lymph which enters the left subclavian after its admixture with the intestinal chyle in the thoracic duct, has been derived from the substance of the viscera and other soft parts, formerly secreted from the blood, and, therefore, already imbued with an animal nature, and easily, without doubt, again miscible with the mass of blood, to which it does but return.

449. Something is contributed by the slow and almost stillatitious manner in which the chyle drops into the blood through the last valve of the thoracic duct; so that these very minute portions are the more intimately combined with the blood.

450. The heart, by means of the remarkable papillary muscles of the ventricles, agitates and mingles the blood just impregnated with fresh chyle.

451. The great importance of the lungs which receive the blood immediately after its addition of fresh chyle, and also of respiration in the business of assimilation *, will be evident on considering the extraordinary vascularity of those organs, and their constant and regular motion.

452. The remaining part of sanguification is accomplished by the general circulation, and the powers which assist it, particularly by muscular motion, &c.

453. Although so many means are provided for the combination of the chyle with the blood, and although the

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* Especially, according to the opinion of Cuvier, in the conversion of the chyle into the lymphatic or fibrous part of the blood. Leçons d'Anatomie Comparée, t. i. p. 91. t. iv. p. 304. Thomson's System of Chemistry, v. iv. p. 497. Bostock's work on Respiration, recommended above.

constituents of the chyle somewhat resemble those of this fluid; nevertheless, it is commonly asserted, that many hours are required for the complete change of the colour of the chyle and its assimilation. Besides other arguments in favour of this assertion, the pathological fact is urged, that chyle is frequently seen in blood drawn many hours after digestion. I myself have witnessed this appearance in cases where the blood too evidently bore an inflammatory disposition, to use a common-place phrase; but I am persuaded that no inference can be drawn hence, in regard to the healthy state, which alone is the object of physiology.

SECT. XXXI.

OF NUTRITION.

454. BESIDES the function of the blood formerly described—of distributing oxygen through the system and removing carbon, its principal use is to afford nourishment to the body in general, and to the secreting organs the peculiar fluids which they possess the power of deriving from it. Nutrition shall be first examined.

455. *Nutrition* is the grand characteristic of nature, and the common and highest prerogative of the animal and vegetable kingdoms, by which these, beyond all measure, surpass, even at first sight, all human machines and automats. Upon these no artist can bestow the faculty, not to say of increasing and of coming to perfection, but even of existing independently, and repairing the incessant losses from friction *.

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* "Nutrition, in fact, appears to be a continued generation," according to the observation of the very ingenious Ent. Vide his work, before praised, at p. 290.

456. By the nutritive faculty of the body, its greatest and most admirable functions are performed; by it we grow from the first of our formation, and arrive at manhood; and by it are remedied the destruction and consumption which incessantly occur in our system during life.

457. Respecting the nature of this consumption, it has been greatly disputed, whether it affects the solids *, or whether, according to some very acute writers, these, when once formed and perfected, remain invariably entire.

458. There can be no doubt that some of the similar solids, v. c. the epidermis and nails, are gradually destroyed and renewed; and the same is proved respecting even the bones, by the well known experiment of dying them with madder root; and by the remarkable attenuation of the flat bones, especially of the skull, from defective nutrition in old age (A).

459. If I am not mistaken, those solid parts undergo this successive change, which possess the reproductive power,—an extraordinary faculty, by which not only the natural loss of particles, but even the accidental removal of considerable parts, from external injuries, is repaired and perfectly supplied, as the bones and a few other parts sufficiently demonstrate.

460. On the other hand, I have been led by many experiments to the conclusion, that this genuine reproductive power appears completely bestowed upon no similar parts

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* Vide the celebrated V. J. Beruvuille's Diss. de Nutrit. Groning. 1669. 4to. He estimates the continual, though insensible, loss and reparation of the solids so high, that the body may be said to be destroyed and renewed every three years.

which possess any other vital power besides *contractility*, i. e. *irritability*, *sensibility*, or a *vita propria* *.

461. In these parts, therefore, whose vital powers are of an higher order, the parenchyma constituting their base, appears permanent, and is liable to this change only,—that the interstices of the fibres and parenchyma, while nutrition is vigorous, are constantly full of nutrient animal gelatine; but, when nutrition languishes, they are deprived of their gelatine, collapse, and consequently become thin.

462. For as the plastic lymph, the importance of which has been frequently mentioned, is readily converted into cellular membrane, so it appears to constitute the principal material of the body, and, as it were, the animal gluten, which is nourished by its means.

463. During the growth of the body, peculiar powers are exerted, by which the lymph deposited in the cellular membrane by the blood vessels is properly distributed, and intimately assimilated to the substance of each organ, &c. This is referrible, both to the laws of affinity, by which

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* That the corium is not really reproduced, is probable, not only from its perpetual cicatrices (for some contend that the matter of those does not continue, but their form only, which is preserved by a perpetual apposition of fresh particles in the room of the decayed and absorbed), but much more by the lines and figures which are made upon the skin, by the singular art of pricking it with a needle, (a process denominated by the Otaheiteans *tattooing*) and imparting to the corium a blue or red colour, as permanent as the cicatriculæ, by means of charcoal powder, ashes, soot, the juices of plants, or galls; on the other hand, the red hue imparted to the bones, by means of madder, quickly disappears, as these parts undergo a continual renovation.

particles attract, and, as it were, appropriate others which are similar and related to themselves; and to the *nisus formativus*, which I shall enlarge upon hereafter, and to which the proper application of shapeless elementary matter, and its modification to particular forms, must be ascribed.

464. To both these powers, I conceive, must be particularly attributed the nutrition of such similar parts as are not supplied with blood; but are, nevertheless, at first generated by a most powerful and infallible *nisus*, grow, are nourished, and, if destroyed by accident, are very easily repaired; such are the nails, hairs, &c.

465. As this appears to be the true account of nutrition in general, so, on the other hand, it evidently has great varieties of degree and kind, especially where, from the more or less lax apposition of the nutritious matter, the structure of the similar parts is more or less dense, and the specific weight of the whole body more or less considerable. In this respect, not only individuals, but whole nations differ from each other. The Jakats and Burats, who are remarkable for the lightness of their bodies, are a sufficient example of this.

NOTE.

(A) The redness imparted to the bones by feeding animals with madder, does not prove that the matter of the bones is constantly changing; because the opinion that the madder unites with the phosphate of lime in the blood, and thus reddens all

the bony matter subsequently deposited, is erroneous. Mr. Gibson proved, by numerous experiments, that the serum has a stronger affinity than the phosphate of lime for madder. The serum being charged with madder, the phosphate of lime of the bones, already formed, seizes the superabundant madder, and becomes red. If the madder is no longer given to the animal, as it is continually passing off with the excretions, the stronger attraction of the serum draws it from the bones, and they re-acquire their whiteness. Manchester Memoirs, vol. i.

SECT. XXXII.

OF THE SECRETIONS IN GENERAL.

466. BESIDES the nutritious fluids, others of various descriptions are produced from the blood, by means of *secretion*, which Haller, no less than his predecessors, declared with truth to be among the most obscure parts of physiology.

467. The secreted fluids on the one hand differ so considerably among themselves, and on the other, have so many points of resemblance, that their classification cannot but be extremely arbitrary. If we arrange them according to the degree of difference between them and the blood from which they are formed, they will stand in the following order:

First, the *milk*, which may be in some degree considered as chyle reproduced, and appears formed by the most simple process from the blood newly supplied with chyle. Next, the *aqueous* fluids, as they are denominated from their limpid tenuity, although the greater part differ importantly from water in the nature of their constituents, and especially in the proportion of albumen. Such are the humours of the eye; the tears; in all probability, the vapour contained in the cellular interstices, and the cavities of the abdomen and thorax; nearly similar, also, is the fluid of the pericardium and of the ventricles of the brain;

the liquor amnii of pregnancy, and the *urine* remarkable for the peculiar nature and mixture of its constituents, are generally enumerated among these.

The *salivary fluids*, concerned in mastication, digestion, and chylification, appear more elaborated. Next the mucous, which line the cavities of most of the organs performing the natural and genital functions, and likewise the tract of the nostrils, larynx, and trachea. The mucus within the eye, and under the epidermis, is nearly similar. In the same class may be included the cerumen of the ears, the unguent of the meibomian glands, of the joints, and, perhaps, the nameless fluid poured forth into the vagina, during the venereal œstrum.

The *adipose* are, besides the common fat, the medulla of the bones and grease of the skin.

Related to these are the secretion of the corona glandis under the preputium, and of the external female genitals.

The truly *serous*, or albuminous, are the fluid of the ovarian vesicles of De Graaf; and the liquor of the prostate.

The *semen virile* and the *bile* are each sui generis.

468. It is obvious that so great a variety of secreted fluids cannot be secreted from the mass of blood in the same way, nor by similar organs. Their chief distinction is the simplicity or complexity of their preparation.

469. The most simple mode of secretion is diapedesis, or transudation; which is the case with the fat and bony fluid.*

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* Physiologists have given different explanations of secretion. Some assert that every fluid is formed by passing merely through inorganic pores from the blood: others altogether deny the exist-

470. Secretion by glands is more complicated. Such is considered the secretion even by follicles and cryptæ, found, v. c. in some parts of the corium, the fauces and aspera arteria. These are denominated the most simple glands.

Properly speaking, the conglomerate (as they are called, to distinguish them from the lymphatic conglobate) are the only true secreting organs; such as the salivary and lachrymal, the pancreas and breasts. They are provided with an excretory duct coming immediately from the large lobes, which are composed of others, smaller, and so intricate in their structure, as to have been the source of warm disputes in the schools of medicine. Malpighi considered the miliary globules easily discoverable in most glands as acini internally excavated.

Ruysch, on the contrary, contended that these supposed hollow acini, were nothing more than glomerules of blood vessels,—an opinion far more consistent with microscopical observation, and the effects of minute injection.

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ence of these pores. I think much of this is a verbal dispute. For on the one hand, I cannot imagine how inorganic pores can be supposed to exist in an organized body, for we are not speaking of the common interstices of matter, in physics denominated pores; and I am persuaded that every opening in organized bodies is of an organic nature, and possesses vital powers exactly correspondent. On the other hand, these openings or pores in the coats of the vessels, evidently are little different in function from the cylindrical ducts, through which fluids are said to percolate in conglomerate glands and secreting viscera: for this percolation depends less on the form of the organ than on its vital powers.

Vid. Schreger's *Fragmenta.*

P. Lupi's Nova per Poros inorganicos Secretionum Theoria Refutata, p. Romæ, 1793, ii. Vol.

Kreysig's Specimen Secundum, formerly mentioned.

471. The structure of some secreting organs, especially of the liver and kidnies, the latter of which strikingly exhibit the glomerules of Ruysch, or the acini of Malpighi, are not, excepting in their peculiar parenchyma, very dissimilar from this structure, and indeed throw considerable light upon this point. In these, small twigs arise from the sides of the capillary arteries, and run into vascular glomerules, hanging like grains as from stalks; from the arterial glomerules first spring very minute colourless secreting vessels, whose origin from the extremities of arteries, was formerly alluded to; the radicles of veins into which the arteries are continued, convey back into the venous trunks the blood deprived of the secreted fluid.

472. The organization of other secreting parts is evidently peculiar, v. c. of the testes, which are composed of very long and numerous vessels, closely compacted, &c.

473. That the different nature of the secreted fluids depends, not so much on the size and external form of the secreting organs, as upon their interior structure and corresponding vital powers, is rendered probable by many of our fluids, which, although secreted by organs at first sight very different from each other, have considerable resemblance to each other in their nature; v. c. the saliva and gastric juice. And comparative anatomy teaches us, that the same fluids are formed by organs very different in external appearance, in different animals.*

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* Compare the form of the kidnies in mammalia with the true conglomerate glands, which supply their place in birds; or the pancreas of warm-blooded animals with the pyloric appendices, whose appearances vary in different fish, and secrete a fluid very similar to the pancreatic.

474. I shall now investigate the causes why particular fluids are found in particular organs,—the most difficult part of the doctrine of secretion, and still open to many doubts.

475. There can be no question that the absolute cause of the variety of secretions is referrible to the intimate nature of the secreting organ. This again depends in the conglomerate glands and secreting viscera especially, both upon the direction and distribution of the secreting blood vessels, and upon the peculiar *parenchyma* of each secreting organ, in some instances distinguishable at first sight from the substance of every other part.

476. It is likewise probable, and indisputable arguments in favour of the opinion have been continually afforded in the course of this work, that secreting organs have not only a peculiar parenchyma, but a *vita propria*, viz. a singular species of vitality distinct from the common vital powers of contractility, irritability, and sensibility.

477. The absorbent system seems of much importance in the business of secretion. In every secreting organ, it absorbs and conveys to the blood a fluid which is, as it were, contaminated by the secretion of the part: v. c. a bilious fluid in the liver; a spermatic in the testes. A constant circle would, therefore, appear to exist in the secretory system, so that the elements of the secretions are incessantly carried to the blood from the secreting organs, and when they have returned to the organs are the more easily attracted by a species of affinity, and draw with them those parts of the blood whose nature is related to their own.

478. The blood from which some secretions are produced, is endowed with peculiar qualities. The bile, for

example, is derived from blood, which contains an abundance of carbonaceous element.

479. I omit other assistances afforded to certain secretions; v. c. congestion and derivation so striking in the secretion of milk, &c.

480. There is this difference between the different fluids secreted by the organs and powers now described,—that some pass to the place of their destination immediately, while others are deposited in receptacles, and detained there for some length of time, becoming more perfect previously to their excretion. The milk in its ducts, the urine, bile, and semen in their respective bladders, and the serum contained in the vesicles of De Graaf, are examples of this.

SECT. XXXIII.

OF THE FAT.

481. OF most of the secreted fluids, a concise and connected view of which was given in the last section, distinct mention has been made in its proper place: the rest shall be described as opportunity may permit. Two remain, which cannot be discussed in a more proper place than the present,—at the close of an inquiry into the natural functions. The one,—the fat, is a part of the system; the other,—the urine, is excrementitious. Each shall be separately examined.

482. The fat is an oily fluid, very similar in its general character to vegetable oils, bland, inodorous, lighter than water; containing, besides the two elements common to water, the oils just mentioned, and to wax, viz. carbon and hydrogen, sebacic acid, which is pretty similar to the benzoic.

483. When secreted from the blood, and deposited in the mucous tela, it exists in the form of drops, divided by the laminæ of the tela, in a manner not unlike that in which the vitreous humour of the eye is contained in cells very analogous.

484. The relation of fat to different parts is various. In the first place, some parts, even whose mucous tela is

extremely soft and delicate, never contain fat. Such are the palpebræ and penis.

In very many parts, it is diffused indefinitely, especially in the panniculus adiposus, the interstices of the muscles, &c. In some few, it is always found, and appears to be contained in certain definite spaces, and destined for particular purposes. Such I consider the fat around the basis of the heart:* and in the mons veneris, where it forms a peculiar and circumscribed lump.†

485. Its consistence varies in different parts. More fluid in the orbit, it is harder and more nearly resembling suet around the kidnies.

486. It is of late formation in the fœtus; scarcely any trace of its existence is discoverable before the fifth month after conception.

487. There have been controversies respecting the mode of its secretion. Some, as Hunter, contending that it is formed by peculiar glands; others, that it merely transudes from the arteries. Besides other arguments in favour of the latter opinion, we may urge the morbid existence of fat in parts naturally destitute of it, a fact more explicable on the supposition of diseased action of vessels, than of the preternatural formation of glands. Thus, it is occasionally formed in the orbits; a lump of hard fat generally fills up the place of a removed testicle; and steotoms have been found in almost every part of the body.

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* Hence it is clear how many exceptions must be made to the assertion of the celebrated Fourcroy,—that fat is an oily matter, formed at the extremities of arteries, and at the greatest distance from the centre of motion and animal heat.

† I found it more remarkable in the body of a female of the genus simia cynomolgus, from which, by means of cold, I was able to remove it entire.

The glands which secrete the fat, are purely imaginary. Whatever may be the truth of this matter, the deposition and absorption of the fat take place with great rapidity.

488. The use of the fat is multifarious. It lubricates the solids and facilitates their movements; prevents excessive sensibility; and, by equally distending the skin, contributes to beauty.

I pass over the particular uses of fat in certain parts, v. c. of the marrow of the bones. During health, it contributes little or nothing to nourishment.* The modern opinion has more probability,—that it affords a receptacle for the superfluous hydrogen, which could not otherwise be easily evacuated.

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* P. Lyonet conjectures with probability, that insects destitute of blood derive their chief nourishment from the fat in which they abound.

Tr. Anat. de la Chenille qui ronge le Bois de Saule, p. 428, 483, et seq. præf. p. 13.

SECT. XXXIV.

OF THE URINE.

489. BESIDES the nutritious (4) fluids and those which form a part of our system, others are superfluous and excrementitious, commonly termed the excrements of the second digestion, and are of two orders. The one exhaled by perspiration, of which we treated formerly; the other, the *urine* streaming from the kidnies.

490. The kidnies are two viscera, situated in the loins on each side, behind the peritonæum: rather flattened, more liable than any other organs to varieties of figure and number; suspended by the emulgent vessels, which are excessively large in proportion to the kidnies, and imbedded in sebaceous fat. (485.)

491. They are enveloped in a membrane of their own, which is beautifully vascular; and each, especially during infancy, consists of eight, or rather nine smaller kidnies, which again consist, Ferrein asserts, of seventy or eighty fleshy radii, denominated by him pyramides albidæ.

492. A kidney, if divided horizontally, presents two substances; the exterior, called *cortex;* the interior, *medulla.* Each abounds in blood vessels, but the cortical por-

tion has likewise very minute colourless vessels, which secrete the urine;* the medullary part contains those which carry it off. These secreting ducts arising from the arteries in the manner formerly described, (471) are united with glomerules, which adhere to the cortical part, and constitute the greatest proportion of it. They may be readily distinguished from the excreting or Bellinian tubes, in which they terminate. These, pursuing a straight course, run from the cortical to the medullary substance, of which they constitute the greatest part, and after having coalesced into fewer trunks, their mouths perforate, like a sieve, the papillæ of the pelvis of the organ.

493. The number of these papillæ usually corresponds with that of the lobes which forms the kidnies, and convey the urine secreted in the colourless vessels of the cortex, and passing through the Bellinian tubes of the medulla into the infundibula, which finally unite to form a common pelvis.

494. The pelvis is continued into the ureters, which are membranous canals, very sensible, lined with mucus, extremely dilatable in the human subject, of unequal size in different parts, and inserted into the posterior and inferior surface of the bladder in such a way, that they do not immediately perforate its substance, but pass a short distance between the muscular and nervous coats, which at that part are rather thicker than elsewhere, and finally

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* These secreting ducts appear to have imposed upon Ferrein as a new description of vessels, which he called neurolymphatic, or white tubes, and of which he imagined the whole parenchyma of the viscera to be composed. He affirmed that they were of such tenuity, that their length in each kidney of an adult man was equal to 100 orgyæ, or 5 leucæ.

open into its cavity by an oblique mouth. This peculiarity of structure prevents the urine from regurgitating into the ureters from the bladder.

495. The urinary *bladder*, varying in shape according to age and sex, is generally capable, in the adult, of containing about two pounds of urine. Its fundus, which, in the fœtus terminates in the urachus, is covered posteriorly by the peritonæum. The other coats correspond with those of the stomach.

The *muscular* consists of interrupted bands of fleshy fibres, variously decussated, surrounding the bladder. These are usually called the detrusor urinæ: the fibres which imperfectly surround the neck, and are inconstant in origin and figure, have received the appellation of sphincter.

The *nervous* chiefly imparts tone to this membranous viscus.

The *interior*, abounding in cribriform follicles, is lined with mucus, principally about the cervix.

496. The urine conveyed to the bladder, gradually becomes unpleasant by its quantity, and growing urgent inclines us to discharge it. For this purpose the *urethra* is given, which varies with the sex, and will be farther considered in our account of the sexual functions.

497. The bladder is evacuated by the constriction of the sphincter being overcome both by the action of the detrusor (495), and by the pressure of the abdomen. To these in men is superadded the action of the acceleratores, which force out the drops of urine remaining in the bulb of the urethra.

498. The nature of the urine varies from age, season of the year, the length of the period since food or drink

was taken, the quality of the ingesta,* &c. The urine of an adult, recently made after a tranquil repose, is generally a watery fluid of a nidorous odour, and of a lemon colour, which qualities depend on a peculiar uric substance, besides a variety of other matters held by the water in solution, and differing under different circumstances. There is a remarkable quantity of phosphoric acid united with other constituents, forming phosphates of soda, ammonia, and lime. A peculiar acid, the lithic or uric, is found in the urine alone.

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* The specific quality of some ingesta, manifest themselves in the urine so suddenly, even while blood drawn from a vein discovers no sign of their presence, that physiologists have thought that, besides the common channels there must be some private ways running directly from the alimentary canal to the kidnies. Greniand sur la Nutrition, p. 115.

Darwin's Zoonomia, vol. i. § 29. Home. Philos. Transact. 1808.

SECT. XXXV.

OF THE GENERAL DIFFERENCES OF THE SEXES.

499. THE functions hitherto examined are common to both sexes, but some are performed very differently in each. The most prominent differences shall be reviewed previously to our entering upon the sexual functions, properly so called.

500. In general, each sex has its peculiar form: more or less striking after birth, but not so obvious in the young fœtus, for the genitals of the male and female, at this period, are not at first-sight different, on account of the clitoris being remarkably large, and the scrotum scarcely visible*.

501. During infancy, the general form is but little different, but becomes more so as age advances; when the round and plump breasts, the general conformation, the delicacy and softness of the female, form a striking contrast with the sinewy and robust body of the male.

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* This I lately found confirmed in twin abortions of different sexes, and of about sixteen weeks formation, in which, although they were most beautifully and correctly formed, the difference of the genitals was not at first discoverable. In every other respect, in the general figure, physiognomy, the dimensions of the loins, &c. they were perfectly similar.

502. The relation of parts, in well-formed females, is extremely different from that in the male. For instance, in the female the face is proportionably smaller, the abdominal and lumbar portion of the trunk larger, the hips broader, not however, if well formed, broader than the shoulders; the buttocks larger, the legs in their descent gradually approaching the knees.

503. A similar difference is remarkable in the osseous system. In females, the bones are, cæteris paribus, smoother and rounder, the cylindrical more slender, and the flat thinner. To pass over individual differences, v. c. the very slight prominence of the frontal sinuses, the more elliptic edges of the alveoli, the comparative narrowness of the chest, and greater capacity of the pelvis, the difference of the clavicles, thigh bones, &c.

504. With respect to the soft parts, the female mucous tela is more lax and yielding, so as to dilate more easily during pregnancy; the skin is more delicate, and of a clearer white, from the quantity of fat below it. The hair of the head is commonly longer; but other parts, which are covered with hair in men, are either quite smooth in women, as the chest and chin; or less hairy, as the perinæum; or smaller in circumference, as the pudenda; or covered with merely a very delicate and soft down, as the arms and legs.

505. Among the particular differences of function, must be enumerated the pulse, which is, in females, cæteris paribus, more frequent (116); the quantity of blood too passing to the abdomen is greater. The lungs, on the other hand, are smaller, from the greater narrowness of the chest, which is however more moveable above. The os hyoides is much smaller, the larynx less capacious and

scarcely prominent: whence the voice becomes more acute.

506. As to the animal functions, the nervous system of females is far more mobile, and the propensity to the passions stronger. On the other hand, the muscular system is weaker, and the muscles (with the exception of the glutœi, psoæ, quadrati lumborum, and a few others) proportionally smaller.

507. In regard to the natural functions, the stomach, and the appetite for food, are less*; the growth of the body more rapid, and the periods of dentition, puberty, and full growth earlier.

508. But by far the greatest difference exists in the genital functions, which are intended in man for impregnating, and in women for conceiving. The fuller investigation of these now remains to be prosecuted.

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* Hence genuine and indubitable cases of long abstinence from food, have generally occurred in females.

Vide, among many others, Fl. James Voltelen's Diatr. Memor. septennis apositiæ historiam exhibens. Lugd. Bat. 1777. 8vo.

SECT. XXXVI.

OF THE GENITAL FUNCTION IN MAN.

509. THE genital fluid is produced in the testicles, which hang in the scrotum, by their *spermatic chords*, through a ring, called abdominal; or through, more properly, a fissure in the tendon of the external oblique muscle of the abdomen. Besides lymphatics, three orders of vessels are found in the testes.

The *spermatic artery*, which is, in proportion to the fineness of its caliber, the longest artery, by far, in the system, and conveys blood to the testicle immediately from the aorta.

The *ductus deferens*, which carries to the vesiculæ seminales the semen separated from the arterial blood.

The *pampiniform plexus* of veins, which return to the cava or renal vein the blood remaining after secretion.

510. The testes are not always suspended in the scrotum. In the very young male fœtus, they are placed in a far different situation, the nature and successive changes of which were first accurately investigated by Haller, but have since been variously explained, and the causes of which change of situation have given rise to numerous controversies. I shall derive my account of this subject from the natural appearances which I have observed in a great number of small embryos, dissected with this view.

511. On opening the lower part of the abdomen of a young fœtus, there appears in each groin, at the ring of the oblique muscles, a very narrow opening in the peritonæum, leading downwards to a narrow passage, which perforates the ring and runs to a peculiar sac, extended beyond the abdominal cavity towards the scrotum, interwoven with cellular fibres, and destined for the reception of the testicle.

512. At the posterior margin of the abdominal ring, there is sent off another process of peritonæum, running upwards, and appearing, in the young fœtus, as little more than a longitudinal fold, from the base of which arises a small cylinder, or rather an inverted cone, which terminates above in a globular sac, containing the testis and epididymis, so that the testis, at first sight, resembles a small berry, resting on its stalk, and appears hanging, like the liver or spleen, into the abdomen.

513. The vessels which afterwards constitute the spermatic chord, are seen running behind the very delicate and pellucid peritonæum; the spermatic artery and vein descending along the spine, the vas deferens passing inwards in the loose cellular substance behind the peritonæum to the neck of the bladder. They enter the testis in the fold of peritonæum just mentioned.

514. After about the middle period of pregnancy, the testes gradually descend, and approach the passage before spoken of (511), the fold of peritonæum becoming at the same time doubled together with the cylinder, until they lie directly over the opening of the passage.

515. The testis being now ready for its descent, the opening which was hitherto small, becomes dilated, so as to allow the organ to pass the abdominal ring and passage, and descend into the bulbous sac (511); after this

occurrence, the opening soon becomes strongly closed, and even unites together, leaving scarcely any vestige of itself in infancy.

516. In proportion to the slowness with which the testis proceeded towards the opening, does its transit through the abdominal passage appear rapid, and, as it were, instantaneous. It is common either to find, in mature fœtuses, the testis lying over the peritonæal opening, or, having passed this, to find it in the groin; but I once only met with the right testis, in a twin fœtus, at the very time when it was adhering, and in a manner strangled in the middle of the passage, just about to enter the sac; in this instance the left testis had passed the abdominal canal, and was already in the sac; the abdominal opening was perfectly closed.

517. This remarkable passage of the testis from the abdomen through the groin, is limited to no period; but would seem to occur generally about the last month of pregnancy; not very rarely, however, the testicles are found in the abdomen or the upper portion of the groin at birth. For they have always another part of their course to finish, after leaving the abdomen, viz. to descend, together with their sac, from the groin into the scrotum.

518. Repeated observation demonstrates this to be the true course of the testicles. To assign the *powers* and *causes* of its accomplishment is no easy matter. For I am every day more convinced, that neither of the powers to which it is usually ascribed, (viz. the action of the cremaster or diaphragm, or the mere contractility of the cellular membrane, which is interwoven with the tendinous fibres, around the cylindrical process of peritonæum, called the Hunterian gubernaculum) is sufficient

to explain so singular a movement, and least of all to explain the transit of the testis through the passage so often mentioned: but that the whole affords a striking illustration of a vita propria, without the peculiar influence of which, so remarkable and unique a course, similar to no other function of the system, can be even imagined.

519. The coats of the testis, after their descent, are conveniently divided into *common* and *proper*.

The common is the *scrotum*, consisting of the skin, having a very moderate substratum of fat, and differing from the rest of the integuments in this,—that its appearance is continually changing, sometimes lax and pendulous, sometimes (especially during the venereal orgasm and the application of cold) constricted and rigid; and in the latter case, singularly marked by rugæ and furrows.

520. Exterior to the proper coats, the *dartos* lies immediately under the scrotum, and is endowed with a peculiar and strong contractile power, which deceived Winslow, Haller, &c. into the belief of the presence of muscularity.

521. Next to this, with the intervention however of much soft cellular substance, are found the three orders of *tunicæ vaginales;* viz. an exterior *common* to the testis and spermatic chord, and to which the *cremaster* muscle adheres by disjoined bundles of fibres; and two interior, one *proper* to the chord, and one to the testis; the fundus of the latter of which usually adheres to the common coat, but is internally moistened, like the pericardium, by a lubricating fluid.

522. The origin of these coats,—the subject of so much controversy, may, I think, be readily explained, from the circumstances attending the descent of the testis.

The *common* coat arises from the descending (511) bulbous sac or peritonæal process.

The *proper* coat of the *testis*, from that portion of the peritonæum which, ascending from the cylinder, originally invests the testis.

The coat *proper* to the *chord* from that fold and short cylinder of the peritonæum in which the fold terminates before it surrounds the testicle.

523. To the body of the testis there adheres very firmly, like the bark of a tree, a coat called *albuginea*, through the combination of which with the internal part of the vaginal coat, blood-vessels penetrate into the pulp of the testis. This is entirely composed of innumerable vessels, about a span in length, convoluted into lobules, both conveying blood and secreting semen, which they carry through the rete vasculosum of Haller, and the vasa efferentia of de Graaf, to the apices of the cones of the epididymis.

524. The *Epididymis*, lying on the side of the testicle, and consisting of one vessel about thirty feet in length, is less, and divided into about twenty glomerules or cones at the part called its head, and is continued into the vas deferens, at its lower part, which gradually becomes thicker, and is denominated its tail.

525. Each vas deferens, ascending towards the neck of the urinary bladder, and converging towards the other under the prostate gland, is then reflected and dilated into the vesiculæ seminales, in such a manner, that the common mouth, both of the vesicles and vasa deferentia, opens into the urethra, behind the caput gallinaginis.

526. The *vesiculæ seminales*, which adhere to the posterior and inferior surface of the bladder, surrounded by an abundance of fat, resemble two little intestines, va-

riously reflected, and branching into numerous blind appendices.

They consist of two coats, similar to those of the gall bladder; the one strong, and of the description usually termed nervous; the other interior, delicate, abounding in cells, and divided into hollow compartments by prominent ridges, like those found in the cervix of the gall bladder.

527. In these passages is slowly and sparingly secreted, from the time of puberty, the *semen*, a very important fluid, of a milky yellowish colour*, of a peculiar odour, of the same viscidity as mucus, and of great specific gravity, greater indeed than that of any other fluid of the body†.

528. Semen has also this peculiarity, first observed by L. Ham Dantiscan, in the year 1677, of being animated by an infinite number of small worms visible by the microscope, of the kind denominated infusoria, and of different figures in different kinds of animals. In man these spermatic animalcules are oval, and have very fine tails. They are said to be found in prolific semen only, so that they are in some degree an adventitious criterion of its prolific maturity. I say adventitious, because I hope there is no necessity, after so many weighty argu-

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* The opinion of Herodotus, respecting the black semen of Ethiopians, refuted in ancient times by Aristotle, has, to my surprise, been taken up in modern times by Le Cat, De Pauw, Wogler, &c.

† F. B. Ossiander asserts, "that fresh semen emitted under certain circumstances, is occasionally phosphorescent." De causa insertionis placentæ in uteri orificium. Gotting. 1792. 4to. p. 16.

ments and observations at present to remark, that they are not the fecundating principle, and much less the germs of the future offspring.

529. The genital fluid gradually collected in the vesicles is retained for subsequent excretion, and by its stay experiences changes nearly similar to those of the bile in the gall bladder; viz. of becoming more inspissated and concentrated by the removal of its watery portion*.

530. While the whole of the testis and spermatic chord abound in lymphatic vessels, which carry back to the blood a fluid with a seminal impregnation, and thus facilitate the secretion of semen in the manner before described (477); so the vesiculæ seminales are likewise furnished with a similar set of vessels, which, by absorbing the inert watery part, render the remaining semen more powerful.

531. But I very much doubt, whether the semen is ever absorbed during health; still more, that it ever passes into the neighbouring veins; and most of all, that by this absorption, if it does occur, unseasonable venereal appetites are prevented; since, if we compare the phenomena of animals procreating at particular periods, with

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* A parodoxical opinion was formerly entertained by some, that the semen is not discharged from the vesiculæ seminales, but from the vasa deferentia, and that the fluid of the vesicles is not truly spermatic and derived from the testis, but of quite another kind, secreted in peculiar glands belonging to the vesicles. This has gained some advocates among the moderns. J. Hunter, on certain parts of the Animal Economy, p. 27. J. A. Chaptal, in the Journal de Physique. Febr. 1787. p. 101. It has been refuted by Sömmering, in the third volume of the Bibliothica Medica, which I edited, p. 87.

the constitution of those which are castrated, we must conclude, that this absorption is rather the cause of ungovernable and almost rabid lust.

532. I conceive that this end is accomplished in a very different mode, by a circumstance which occurs, as far as I have been able to discover, in no animal but man,—by *nocturnal pollutions*, which I regard among the natural excretions, intended to liberate the system from the otherwise urgent superfluous semen, more or less frequently, according to the variety of temperament and constitution*.

533. The semen is never discharged pure, but mixed with the *prostate fluid*, which is of the appearance of the white of egg, and has acquired its name from the organ by which it is produced. This is a body of some size, of a singular and very compact substance, lying between the vesiculæ seminales and bulb of the urethra, and commonly denominated *prostate gland*. The passages for the course of its fluid are not well known, unless perhaps they communicate with the sinus of the seminal caruncles, the middle of the orifice of which opens into the urethra, between the two mouths of the seminal vesicles.

534. The male *urethra* is the common emissary of three different fluids: the urine, semen, and prostate fluid. It is lined with mucus, which proceeds from numerous sinuses dispersed along the canal. We find it surrounded

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* I willingly grant that barbarous nations, of a phlegmatic temperament, and copulating promiscuously, do not require this excretion; but I must contend, that it is a perfectly natural relief, in a young man, single, sanguineous, full of juices, with a strong imagination, and living high, although enjoying the completest health in all other respects.

by a spongy texture, upon which lie two other *spongy bodies* of much greater thickness, constituting the greater part of the penis. The penis is terminated anteriorly by the *glans*, a continuation of the spongy texture, quite covered by a delicate and very moveable skin, which is destitute of fat, and, at the corona of the gland, forms the preputium which moves over the gland as the eyelids do over the eyeball. The internal duplicature of the preputium, changing its appearance, is reflected over the gland, like the albuginea of the eye, and is beset at the corona with many Littrian glands, similar to the Meibomian of the eyelids, and secreting a peculiar grease*.

535. The virile organ thus constructed, enjoys the power of *erection;* i. e. of becoming swollen and stiff, and changing its situation, from the impetuous congestion and effusion of blood into its corpora cavernosa,

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* This, in young men, especially when heated, is well known to accumulate and form an acrimonious caseous coagulum. The inhabitants of warm climates are particularly subject to this inconvenience, and the chief use of circumcision appears to be the prevention of this accumulation. We know, that for this reason Christians in the scorching climate of Senegambia occasionally cut off the preputium; and that uncircumcised Europeans residing in the East, frequently suffer great inconvenience. Guido de Couliaco, the celebrated restorer of surgery in his day who flourished in the fourteenth century, long since said, that circumcision was useful to many besides Jews and Saracens, "Because it prevents the accumulation of sordes at the root of the gland, and the consequent irritation." Chirurg. Tr. vi. doctr. ii. p. m. 111.

either from corporeal or mental stimulus, and of detumifying and collapsing, after the return of the blood.*

536. When in a flaccid state, it is remarkably bent at its origin from the neck of the bladder, and thus perfectly adapted for the discharge of urine, but quite unfit for the emission of semen, because the origin of the urethra then forms an acute angle with the openings of the seminal vesicles.

537. When the penis swells from lust, the prostate fluid generally flows first, and indeed is often discharged pure, but rarely mixed with the urine: its principal use is to be emitted with the semen, either by its albuminous lubricity correcting the viscidity of the former and promoting its emission, or contributing something peculiar to generation.

538. The emission of semen is excited by the abundance of semen in the vesicles, and by sexual instinct: it is effected by the violent tentigo which prevents the course of the urine, and by a kind of spasmodic contraction of the vesiculæ seminales, a convulsion of the levatores ani and of the acceleratores urinæ, and by a short and less violent succussion of the whole system, of an epileptic nature, followed by great depression of the strength†.

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* A phenomenon worthy of remark, from the light which it throws on this function, is the erection so frequently observed in those who are being hanged, and especially in those who are being strangled. Garmann de Miraculis Mortuorum, l. xi. 707. Morgagni de sed. et caus. morb. xix. 19, et seq.

† For which reason Zeno, the father of the Stoic philosophy, called the loss of semen the loss of part of the animating principle.

NOTE.

(A) J. HUNTER'S arguments are the following:—In men who have lost one testicle, the vesicula seminalis on this side is equally full of mucous matter as on the other, and was found so in one instance where the duct had no communication with the testicle. If lascivious thoughts occur, and the semen is not discharged, the testicle swells, and remains so till the semen is emitted. The retraction and compression of the testicles, during coition, also favour the opinion that the semen proceeds immediately from them. In opposition to this opinion it may be urged, that in many cases of relaxation of the genital organs from excessive venery or onanism, mere straining, without any irritation, causes a discharge of true semen,—a circumstance which must here arise from the compression of the vesiculæ seminales, as the straining cannot affect the testicles.

From these circumstances, and from the analogy of form which subsists between the vasa deferentia and vesiculæ seminales, and the hepatic duct and gall bladder, it is probable that the semen, like the bile, is always gradually flowing into the vesiculæ, to become inspissated and ready for emission, and that during coition it flows both from the vesiculæ and testes; but that when the discharge is frequently repeated, it is emitted either without entering the vesiculæ seminales, or after remaining in them a very short time only.

SECT. XXXVII.

OF THE GENITAL FUNCTION OF WOMEN IN GENERAL.

539. As the male organs are fitted for affording, so the female organs are fitted for receiving, and are in a great measure correspondently opposite to the former. In some parts, the organs of each sex are very analogous to each other in structure. Thus the *clitoris* lying under the pubis in the superior commissure of the labia, agrees in many respects with the penis of the male, although distinct from the urethra, and imperforate and extremely small in well-formed women. It is recorded to have been, in some adult females, of as comparatively large size as we stated it usually to be in the fœtus (492), and these instances probably gave rise to most of the idle stories of hermaphrodites. Like the penis, it has its corpora cavernosa, is capable of erection, covered with a prepuce, and secretes a smegma* not unlike the Littrian (525).

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* In warm climates it too is liable to accumulation and acrimony, and has hence given occasion to the custom of female circumcision in many hot parts of Africa and Asia. Carst. Niebuhr has given a representation of the genitals of a circumcised Arabian female, eighteen years of age, whom he himself was singularly fortunate in examining during life, when on his oriental tour. Beschreib. von Arabien. 77. and Osiander's Deukwürdigkeiten für die Heilkunde, &c. vol. ii. tab. vi. fig. 1.

540. From the clitoris the *nymphæ* descend, also occasionally of great size*, the source of other idle tales†, and, like the clitoris, possessing a high degree of sensibility. They appear in some measure to direct the stream of urine, because the opening of the urethra, which is very short in females, and frequently ciliated, as it were, with small papillary folds‡, lies under their commencement.

541. Under the opening of the urethra lies that of the *vagina*, surrounded with various kinds of cryptæ; v. c. the lacuna of De Graaf, and the orifices of the prostates, as they are improperly termed, of Casp. Bartholin, which secrete an unctuous mucus§.

542. Across the opening of the vagina, the *Hymen* is extended,—a membrane generally circular, found, as far

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* Their number has likewise been found various. Neubauer de triplici nympharum ordine. Jenæ. 1774. 4to.

† For example, of the singular ventral skin of the Hottentot women. Wilh. Ten Rhyne, from personal inspection long ago, considered it as enormous pendulous nymphæ. De promontorio b. spei. p. 33. I have treated this point at large in my work, De Gen. Hum. Var. Nat. 242. Steller relates something similar in regard to the Kamtschatkan women. Beschr. v. c. Lande Kamtschatka. 300.

‡ I find the opening of the urethra surrounded with very beautiful cutaneous cilia of this kind, in a remarkable specimen of the genitals in a woman upwards of eighty years of age. The hymen is entire, and all the other parts most perfectly, and, as it were, elaborately formed. They are preserved in my museum, and my friend and colleague, Osiander, has represented them in a plate. Libro Citato. tab. v.

§ Such also are the two foramina, very frequently observed in living women, by J. Dryander, at the extremity of the vagina. Nic Massa's Epistol. Medicin. t. 1. p. 123. b.

as I know, in the human subject alone, and of no physical use hitherto discovered.

The remains of the lacerated hymen become the *carunculæ myrtiformes*, which are of no regular number, and are infallible signs of the loss of virginity.

543. The *vagina*, ascending between the urinary bladder and rectum, consists of a very vascular cellular parenchyma; is surrounded inferiorly by the *constrictor cunni*, and lined internally with a very soft coat, which is marked by two columns of rugæ, an anterior and posterior, pouring forth a mucus into its cavity.

544. Upon the superior extremity of the vagina, rests the *uterus*, suspended on either side by its broad ligaments. Its cylindrical cervix is embraced by the vagina, and perforated by a narrow canal, which, like the vagina, is marked by rugæ, denominated the arbor vitæ, and is generally lined with a viscid mucus at each extremity, but particularly at the superior.

545. The substance of the uterus is peculiar, a very dense and compact parenchyma, abounding in blood-vessels, running in a curious serpentine direction, and destitute of valves. It has also a supply of lymphatics; and a great number of nerves, whence its remarkable sympathy with other parts.

546. The uterus is covered externally with peritonæum; its internal cavity is small, and lined, especially at the fundus, with a soft and very delicate spongy membrane, which is composed, according to some, of colourless vessels, and, according to others, of lymphatic veins.

547. With respect to its muscularity, asserted by some and denied by others, I may remark that I have never yet discovered a true muscular fibre in any human uterus which I have ever dissected, whether impregnated or un-

impregnated, recent or prepared: but it must be allowed, that the fibres, termed by some muscular, have qualities very different from any others observable in the system. I am daily more convinced that the uterus has no true irritability (301), but a vita propria (42), correspondent with the peculiar motions and functions of the uterus, which are not referrible to any properties common to the similar parts (39-41), and which appeared to the ancient physicians and philosophers so peculiar, that the uterus was by them denominated an animal within an animal.

548. From the angles of the roof or fundus of the uterus, arise on each side the *Fallopian tubes*, narrow and tortuous canals, running in the upper part of the duplicature of the broad ligaments, similar in texture to the vagina, but internally destitute of rugæ, and lined by a very soft and delicate spongy substance.

549. The extremity opening into the abdomen is not only larger than that which opens into the uterus, but is surrounded by laciniated or digitated fimbriæ, singular and elegant in structure, which are probably of great importance in conception, since they appear to become turgid as well as the tubes themselves, during the venereal œstrum, and to embrace the ovaria over which they lie.

550. The *ovaria*, or, as they were termed previously to the time of Steno*, the female testes, are composed of a tough and almost tendinous covering, and a dense and closely compacted cellular substance, which contains in each ovarium about fifteen ovula, called Graafian, viz. vesicles, or rather drops of albuminous yellow serum,

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* Steno first asserted, that the testes of women were analogous to an ovarium, 1667. Element. Myolog. Oper. 117.

which coagulates like white of egg, if the ovarium is plunged into boiling water.

551. Such an albuminous drop appears to be what the female contributes in the business of conception, and it is probable, that, during the adult state, one of these drops becomes mature in succession, so that it forces its way and finally bursts the covering of the ovarium, and is received by the abdominal extremity of the Fallopian tube.

552. Besides the albuminous drop, which escapes from the ovarium, another fluid, improperly styled female semen by the ancients, is poured forth during the venereal œstrum. Its nature, source, and quantity, are enveloped in no less mystery than its office.

SECT. XXXVIII.

OF THE MENSTRUA.

553. AN important, and indeed the most frequent function of the uterus, is to afford a menstrual fluid during thirty years, a law imposed upon no other living being,*— for woman, in the words of Pliny, is the only menstruating animal. The females of no nation hitherto explored, are exempt from this law,† which consequently may be re-

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* Most writers upon Natural History, and among the rest Buffon, allows the existence of periodical menstruation in other animals, especially of the order simiæ. But after carefully observing the females of the genera of simiæ, mentioned by him, (v. c. of the simia sylvanus, and cynomolgus, the papio maimon, &c.) for a number of years, I easily discovered that these supposed catamenia in some did not occur at all, and in others of the very same species, were merely a vague and sparing uterine hemorrhage, observing no regular period.

† There is hardly occasion to refute the unfounded assertion, that in some nations, particularly on the Continent of America, the women do not menstruate. This opinion appears to have originated from the circumstance of the Europeans who visited those countries, and saw innumerable women nearly naked, never finding any men-

garded among the requisites in the female sex, for the propagation of the species.

554. The commencement of this function usually occurs about the fifteenth year, preceded by feelings of fulness, by a sense of heaviness in the chest, and of tension in the loins, by lassitude of the limbs, &c. From the first of these symptoms, a reddish fluid generally flows from the genitals, becoming by degrees more deep and bloody, and at length purple. This has a peculiar odour, coagulates but imperfectly, and differs also in other respects from blood. It continues to flow slowly for some days, and the unpleasant symptoms above described at length cease.

555. This red discharge returns after this period about every four weeks, and continues about six days, during which time a healthy woman is supposed to lose, perhaps, from five ounces to half a pound of blood.

556. This action is usually *discontinued* during pregnancy or lactation. It entirely *ceases* after existing thirty years; that is, in our climate about the forty-fifth year.

557. By some, the vagina, by others, and with more probability, the uterus, is considered the seat of this discharge. Arguments adduced against the latter opinion

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strual stains upon them. For this there might be two reasons. First, the American women are, by a happy prejudice, regarded as infectious, while menstruating, and remove from society to the advantage of their health into solitary huts. Again, their extreme cleanliness and the modest position in which they place their limbs, would prevent any vestige of the catamenia from being observable, as Adr. Van Berkel expressly states in his Reisen nach Rio de Berbice und Surinam, p. 43.

from the examples of women menstruating although pregnant, or having the uterus imperforate or prolapsed, more clearly prove the extraordinary compensating powers of nature, which employs new ways, when the customary are impeded. On the other hand, the dissection of women, who have died during menstruation, has discovered the cavity of the uterus bedewed with the catamenia. I say nothing of the a priori argument,—that the end of menstruation is probably to render the womb fit for pregnancy, and for nourishing the fœtus. For the same reasons the arteries rather than the veins appear to be the source of the discharge.

558. The investigation of the causes of the regular periodical return of this hemorrhage is so difficult, that we can obtain nothing beyond probability, and shall not dare to offer any thing merely conjectural.

The proximate cause is supposed to be a *local** plethoric congestion; an opinion with which the symptoms preceding menstruation, and the abundance and nature of the uterine vessels agree very well.

Among the remote causes may be enumerated the erect posture peculiar to the human race; the singular parenclyma of the uterus, and its vita propria.

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* The plethoric universal orgasm, as it was termed, which some formerly regarded as the cause of menstruation, has been long since refuted by more enlightened physiologists. To the arguments of the latter, I may be permitted to add that of the celebrated Hungarian sisters, who from monstrous formation were united together, (63 Note). Although the same blood flowed to the loins of each, they differed frequently both in the period and the quantity of their menstruation.

It will be better to confess our ignorance of the cause of its periodical return, than to indulge in vain hypotheses: all the periodical phenomena of health and disease, *which continue more than twenty-four hours*, are among the mysteries of nature.

SECT. XXXIX.

OF CONCEPTION AND PREGNANCY.

559. I NOW come to the functions for which the genital organs are given us—to conception and the propagation of the species,—in treating which, I shall first merely describe the phenomena which are observed, and afterwards investigate the powers by which they are produced.

560. In the first place, it is worthy of remark, that the human race, unlike most animals, does not copulate at certain periods of the year,* but that every season is equally favourable to the flame of love.

561. When a woman admits the embraces of a man, and both burn with that animal instinct, which is superior to all others in universality and violence, the uterus, I conceive, swelling with a kind of inflammatory orgasm,† and animated

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* Unless the observation made by Wargentin, that there is a greater proportion of births in September, which corresponds with the preceding December, be considered as relative to this point. Vide Swensk, Vetensk. Acad. Hadlingar, 1767, vol. xxviii. p. 249 et seq.

† Ruysch had an opportunity of examining two uteri immediately after impregnation. The one of a common woman, mur-

by its vita propria, draws in, as it were, the semen ejaculated by the male,* and appears to pour forth a fluid of its own against it; the tubes become rigid, and their fimbriæ embrace the ovaria, in one of which a ripe Graafian vesicle, bursting like an abscess, and its albuminous drop of fluid being absorbed by the abdominal opening of the tube, is conveyed to the womb.

562. After the escape of this drop from the ovarium, the lips of the womb are closed by an external cicatrix, and the remaining vascular membrane is converted into a corpus luteum. This at first appears to me hollow and full of a plastic lymph, but in progress of time to become a fleshy nucleus, surrounded with a thick cortex, remarkably vascular.†

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dered by her paramour immediately after connexion. Adversaria Anat. medico Chirurg. Dec. i. tab. ii. fig. 3. The other of a married woman impregnated a few hours previously, and killed in the act of adultery by her husband. Thesaur. Anat. vi. p. 23 et seq. tab. v. fig. 1.

* If we consider the impetus with which the semen is emitted, and as it were swallowed by the uterus, and how small a quantity is proved, by experiments on animals, to be sufficient for impregnation, we shall be able to explain those well established cases of conception, where the hymen was imperforate—cases brought forwards in support of the existence of a seminal aura.

† It is a celebrated question in physiology and forensic medicine, much agitated in late years, whether a corpus luteum is the consequence of a fruitful coition alone, and therefore an infallible sign of conception, or whether it can occur independently of coition, and may therefore exist in virgins. I trust that I have settled this dispute according to the truth, and have shown the conditions under

563. After impregnation, the canal which runs along its cervix, is thoroughly closed, especially towards its superior or internal orifice, so that superfœtation, properly so called,* cannot naturally take place. There are no constant and infallible signs by which the woman herself can be very certain of the changes which occur within during conception.

564. The internal surface of the uterus becomes lined with plastic lymph, which forms the tunica *caduca*, or *decidua* of Hunter:† which is said to consist of two laminæ, the *crassa* investing the uterus excepting at the orifices of

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which it may occasionally take place even in virgins. Specimen, physiologiæ camparatæ inter animantia calidi sanguinis vivipara et ovipara, in the commentat. soc. reg. scientiar. Gotting. vol. ix. p. 109 et seq.

* That different conceptions may occur from the repetition of coition after very short intervals, is proved by the instances of adulterous women, who have brought forth twins resembling different fathers in the colour of their skin: viz. of black women who have brought forth a black and a mulatto, and of European women who have brought forth a white and a mulatto.

† Aretæus Cappadox (de Causis et Sig. Morb. Diuturn. l. ii. c. ii. p. 64 et seq. Boerhave's edition) seems the first who gave a true account of the origin of this membrane. The more accurate notion of it we owe to Wm. Hunter.

After the revival of anatomy, Fallopius restored the knowledge of it. Observ. Anat. p. 207. "The chorion is either the chorion, simply so called, or the *spongy*, *tomentous*, *fungous*, *filamentous*, *reticulated*, of the moderns: the membranous covering of Albinus." Ruysch, as far as my knowledge extends, gave the first plate of it. Thes. Anat. v. tab. i. fig. 1. F. B. C. G.

the tubes and of the canal of the cervix; the other produced after the ovulum begins to be formed and to take root in the decidua, and continued over the rest of the ovum, as the peritonæum is continued over the abdominal viscera. It is therefore denominated the *caduca reflexa.*

565. The *ovulum* is produced before the embryo, which it is intended to receive, but scarcely begins to be formed before the second week from conception. Previously to this period, I very much doubt, whether any vestige of human conception has ever been visible.

566. This ovulum consists, besides the external adventitious covering afforded by the *caduca* of Hunter, of two proper velamenta or membranes.

Of an exterior, the *chorion* of the moderns; the external surface of which is from the first, covered with inexpressibly beautiful knotty fiocculi; whence it has been called the flocculent, leafy, or mossy, chorion. By means of these flocculi, which are the rudiments of the fœtal portion of the future placenta, the ovulum takes root, as it were, in the uterine decidua.

Of an interior, styled amnion, possessing no blood-vessels, delicate and remarkably tough.

567. These two proper membranes of the ovulum differ very much from each other in size in the first week after the formation of the ovum; the chorion appears a large bladder, to which the amnion, a much smaller bladder, adheres in that part only which corresponds with the centre of the external flocculent surface of the chorion.

The remaining space between the chorion and amnion is filled by a clear water, which may be called the *liquor chorii*, of doubtful origin and uncertain duration.

For since the amnion increases more rapidly than the chorion, it approximates to the latter during the first

months after conception, and in proportion to its approximation, this fluid must necessarily be absorbed.

568. The internal membrane of the ovum is filled, from its first formation to the last moment of pregnancy, with the *liquor amnii*, an aqueous fluid, of a yellowish colour, nearly inodorous, of a bland and scarcely saltish taste, commonly thought nourishing, and compared to albumen, from which, however, more accurate investigation proves it to differ considerably.

Its source is doubtful, and cannot be referred to the fœtus, or umbilical chord, since it exists in abortive ovula which contain neither.

Its quantity is inversely as the size of the fœtus. Hence we may conjecture that its use is rather to defend the fœtus while nearly gelatinous and liable to suffer from external injuries, than to afford nourishment. That the portion of fluid which occasionally, although rarely and not naturally, enters the stomach of the fœtus, is not destined to nourish it, is evident from the nature of this fluid, and from the state of the chylopoietic system of the fœtus: to omit arguments deduced from acephalous fœtuses, &c.*

569. The embryo, which swims in this fluid, suspended by the umbilical chord, like fruit from a stalk, begins to be formed from about the third week after conception :† at first it appears to be of a rather globular shape, resem-

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* I trust no one will adduce in objection, accounts of fœtuses destitute of umbilical vessels, who has read those accounts with any attention.

† There is no occasion in our times to refute the false remarks and figures, given by Mauriceau, Kerckring, and others, of fœtuses, one or a few days old.

bling a little bean or kidney. It is from this, that the rudiments of the extremities grow, and the face is at length formed.

570. By nature, woman is *uniparous*, and conceives but one fœtus. Frequently, however, she produces twins, the proportion of which to single births, Süssmilch estimates as 1 to 70.* In these cases, each child has its own amnion, but there is a common chorion.†

571. The medium of connexion between the mother and the child, are the umbilical chord and the placenta into which it is distributed.

572. The *umbilical chord*, which appears coeval with the embryo, varies exceedingly in length and thickness, in the place of its insertion into the placenta, in its varicose knots, &c. It always consists of three vessels twisted together, viz. a vein running to the liver of the fœtus, and two arteries arising from its internal iliacs or hypogastrics. They are separated from each other by cellular septa of various directions, and are throughout narrowed internally by the nodules, or quasivalves of Hoboken.

The reasons of my fixing upon this term, I have explained at large in the Medic. Biblioth. vol. ii. p. 673. How remarkably this was afterwards confirmed by fact, will be found in the same work, vol. iii. p. 727.

* This proportion is not very constant, and there is some national variety in this respect.

Egede expressly mentions the infrequency of twins among the Greenlanders, in his Descr. du Grönland, p. 112.

Their remarkable frequency among the people of Chili is asserted by Molina, in his Saggio su la Storia Naturale del Chili, p. 333.

† Twins are very rarely contained in a common amnion. James de Puyt in his Verhandel. der Zeeuwsch Genootsch. te Vlissingen. t. ix. p. 423, seq.

They are collected into a chord by means of a cellular membrane, which is full of a singular fluid, called Whartonian, resembling gelatine in appearance, and is surrounded externally with a continuation of the amnion.

573. At the part where the chord is united to the fœtus, there runs the *urachus*, which arises from the fundus of the urinary bladder, and lies between the two umbilical arteries. In the human subject, it is pervious but for a very short distance, and, indeed, soon disappears altogether. In other mammalia it leads to the allantoid, which is universally acknowledged to be absent in the human fœtus. For I consider that the problematical *vesicula umbilicalis*, found in human ovula, between the chorion and amnion, is not analogous to the allantoid, but to the *tunica erythroides*, found in the ova of some mammalia, and to the vitellary sac of the incubated egg. It is found in healthy human ovula, after the second or third month from conception, too frequently and of too constant an appearance to be regarded as accidental, morbid, or monstrous.*

574. The blood vessels of the chord pass to the placenta, of whose origin from the flocculent surface of the chorion inserted into the *decidua crassa*, I formerly spoke. Hence we discover how the substance of the placenta is double—the uterine portion derived from the decidua and forming a spongy parenchyma: the fœtal arising from the umbilical vessels distributed on the chorion. The increase of the ovulum is irregular, so that the smooth part of the

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* The opinions both respecting the natural constancy of the vesicula umbilicalis, and its analogy to the *tunica erythroides*, I originally, as far as I know, proposed upwards of twenty years since, in the first edition of these Institutions (1787), and in my *Specimen Physiologiæ Comparatæ* (178), formerly quoted.

chorion grows more rapidly than the flocculent; consequently, the size of the placenta bears a greater proportion to that of the ovum, the shorter the period which has elapsed since conception, and a smaller, as the period of labour approaches.

As pregnancy advances, its texture becomes more compact, sulcated, and lobular on its uterine surface, and more smooth on its interior surface which is covered by the amnion. It varies greatly in size, thickness, figure, and situation, or place of attachment to the uterus; generally it adheres to the fundus; it is destitute of sensibility and true irritability.

575. Although all agree that the placenta is the chief instrument in the nourishment of the fœtus, the true mode of its operation, and its mutual relation to the uterus and fœtus, have given rise to great controversies in modern times. After all, the truth appears to be this,—that no anastomosis exists between the blood vessels of the uterus and of the chord: but that the oxygenized blood which proceeds from the uterus to that portion of the placenta which was originally the decidua crassa, is absorbed by the extreme radicles of the umbilical veins distributed upon the flocculent chorion, and carried to the great venous trunk of the chord; the carbonized blood returning in a similar manner from the fœtus, through the umbilical arteries, being poured into the substance of the placenta, is absorbed by the venous radicles of the uterine portion of the placenta, and returned to the uterus.

This account is supported by very careful but fruitless attempts to inject the umbilical by means of the uterine vessels, and the uterine by means of the umbilical vessels; or to tinge the bones of the fœtus with red, by giving madder to the mother. It is also confirmed by the differ-

ence observable between the blood of the mother and fœtus (B).

576. During the progress of pregnancy, while the fœtus and secundines are increasing, the uterus of course undergoes important changes, not only in size, but in situation, figure, and especially in texture, which is considerably changed both in regard to its blood vessels and the intervening parenchyma, from the constant and great congestion of fluids which occurs.

In proportion as the uterus increases, the blood vessels from being winding and tortuous become straight and larger, and the veins, near the termination of pregnancy, acquire so great a bulk, as to have been taken for sinuses by some anatomists.

The parenchyma becomes gradually more thin and lax, especially in the part nearest the ovum, so that although the gravid uterus is very thick, particularly at its fundus, and in a living and healthy woman is turgid with blood, and replete with vital energy, nevertheless it is soft, and in its general nature, which, as Arantius long since remarked, appears lamellated in advanced pregnancy, extremely different from the firm and compact substance of the unimpregnated uterus.

577. The remaining changes of the gravid uterus, as well as those which occur to the ovum and fœtus, I shall briefly relate in the order of the ten lunar months, according to which pregnancy is at present very conveniently calculated.

578. As the uterus immediately after impregnation always becomes turgid, so from that period increasing in bulk and weight, it descends into the upper part of the vagina, still retaining its former figure during the first months, except that, perhaps, its fundus becomes a little more convex, and the anterior portion somewhat recedes

from the posterior, and that its cavity, before extremely small and triangular, becomes expanded by the fluids of the ovum, and accommodates itself to their subglobular form.

The ovum itself, which about the termination of the first month, is of the size of a pigeon's egg, and possesses both deciduæ separate from each other, and the minute amnion separate from the larger chorion, attains, near the end of the third month, the size of a goose's egg; the decidua reflexa then closely approaches to the crassa, and the amnion to the chorion; the former is filled with the fluid which bears its name, and defends from the pressure of the womb the tender embryo, which is very small in proportion to it, scarcely of the size of a little mouse, and in a variable and depending situation.

579. From the fourth month, the uterus becomes more oval or subglobular, and from the gradual softening, abbreviation, and almost disappearance, or rather lateral distension, of its neck, it inclines upwards and rises to the superior part of the pelvis. At the same time the tubes ascend with the convex fundus of the womb, are extended and elongated, but adhere to the sides of the uterus so firmly, that half of their length only is separate from the latter; and at first sight, they appear to arise from the middle of the uterus,—a circumstance which gave occasion to an erroneous opinion of the enormous increase of the organ. After this period, the fœtus acquires a size more proportional to the capacity of the ovum, and, at the same time, a more firm and globular shape, which it preserves to the end of pregnancy; the head is inclined to the chest, and the back bent, and generally rather opposite to one side of the mother.

580. In the middle of pregnancy,—at the end of the fifth month, so great has the size of the uterus become,

that its fundus is nearly between the navel and pubis, and pregnancy becomes externally evident. After this period, the fœtus by its motion is generally more distinctly perceptible to the mother: this circumstance, however, occurs at no definite time.

581. During the remaining five lunar months, the uterus and fœtus continuing to increase, the fundus of the former reaches the umbilicus about the sixth month; after the eighth, having risen higher, it approaches the umbilicus. In the mean time, the cervix is gradually obliterated, flattened, and attenuated.

582. In the tenth month, the uterus, overwhelmed, as it were, with its own bulk, eleven inches in length and nine or more in breadth, again begins to subside.

Each decidua, but especially the reflexa adhering to the chorion, having for many months grown thinner, now appears a net-work of short white fibres.

The larger diameter of the placenta is nine inches; its thickness one; its weight one pound or upwards.

The length of the umbilical chord is eighteen inches or more. The weight of a full grown fœtus is usually seven pounds; its length about twenty inches.*

The quantity of the liquor amnii is too variable to be defined; but when the fœtus is strong, it seldom exceeds a pound.

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* Its weight and volume are remarkably large in proportion to the mother, if compared with the offspring of many other mammalia. But, notwithstanding this, woman is so far from producing the largest fœtus in this respect, that she is surpassed by many palmated and digitated brutes, whose fœtuses I have now before me.

NOTES.

(A). Dr. Haighton, the lecturer on physiology at Guy's Hospital, contends that the semen passes no further than the vagina, and that conception takes place from sympathy of the ovaries, &c. with the vagina, under the influence of semen and of the circumstances attending its emission. He has never discovered semen in the uterus or Fallopian tubes of animals after coition; and asserts that it has been found there very rarely by other physiologists. He divided one Fallopian tube in rabbits, admitted the male, and afterwards found the ovary on this side was impregnated equally with the other, although no semen could possibly have been brought in contact with it. The secretion of milk in the breasts, the plugging up of the os uteri, and the formation of the decidua previously to the descent of the ovum must be sympathetic, and why not proceed a step farther, he urges, and ascribe the impregnation of the ovarium likewise to sympathy.

In opposition I may remark, that, although in Dr. Haighton's experiments, one Fallopian tube was divided, this did not prevent the semen from entering the uterus, nor, perhaps, from escaping through the divided end of the tube, and coming in contact with the ovarium. The great force with which the semen is emitted, appears intended to propel it farther than the vagina. Again, it may act upon the ovaria by absorption. It is of course absorbed, and, having entered the circulation, will, like purgatives or emetics injected into the veins*, exert its effects upon those parts to which it bears a relation,—upon the

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* Emetics or purgatives, injected into the circulation, produce vomiting or purging, as if they had been swallowed.

ovaria. To ascribe the impregnation of the ovarium, and the resemblance of the child to the father, in countenance, constitution, disposition, &c. as occurs every day, to sympathy with the vagina, is, I conceive, too great an extension of the doctrine of sympathy.

(B) Reasoning on the point, we should conclude that the blood of the fœtus had the same appearance in the arteries and the veins,—that it underwent no changes in the placenta similar to those which occur in the lungs after birth. First, these changes are not required for the support of the temperature of the fœtus, as the heat of the mother accomplishes this purpose. Secondly, after birth, the chemical changes in the lungs are principally intended to discharge from the blood the superfluous carbon of the chyle which has been introduced into it immediately before arriving at the lungs. Now the fœtus is not nourished by chyle, but by blood which has already passed through the lungs of the mother, and can therefore scarcely require any function for the further separation of this carbon. Thirdly, with respect to that portion of superfluous carbon which, after birth, flows through the veins from every part of the system, it is probable that no analogous superabundance of carbon occurs in the fœtus, as in it there is little or no expenditure of nervous energy upon voluntary muscular action, none upon the mental functions, and comparatively little upon the functions of the thorax and abdomen, no secretion of perspiration, little or none of tears, saliva, gastric, pancreatic, or enteric fluids, bile, urine, &c.; in short, scarcely any processes of decomposition, but those of appropriation or composition nearly alone.

But to lay aside reasoning, Fourcroy is almost the only author who has asserted the arterial blood of the fœtus to be different from the venous; and his observations, Berzelius remarks, "seem to have been made by chance, and not to be deduced from any experiment," while "credible authors have asserted that the eye cannot distinguish between the arterial and venous blood of the fœtus." Animal Chemistry, p. 41, 42.

SECT. XL.

OF THE NISUS FORMATIVUS.

583. HAVING simply described the phenomena of conception, and the changes which constant observation shows to occur both to the ovum and the contained fœtus during pregnancy, I now proceed to those powers by which it appears that generation is effected.

584. Even in our memory, some physiologists of reputation have contented themselves with roundly asserting that true generation never occurs, but that the whole human race pre-existed in the genitals of our first parents, in the shape of previously-formed germs, which become evolved in succession. Some of these imagined the germs to be the spermatic animalcules of the male; others imagined them to exist in the ovaries of the mother*.

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* V. C. Haller, an illustrious physiologist, who plainly asserted, *that all the viscera and bones of the future fœtus, nearly fluid indeed, and therefore invisible, were preformed, before conception, in the maternal germ.*

In support of this hypothesis, he argued chiefly from the continuity of the membranes and blood-vessels between the incubated chick and the yolk of the egg.

But the more frequently I have demonstrated the phenomena of incubation in my Physiological Lectures, the less strength have I found in this argument.

585. This hypothesis, if carefully examined, must be rejected. Besides being repugnant to reason, from the superfluous and useless creation which it supposed, of innumerable germs never arriving at evolution; it assumes so many preternatural conditions, and such a multiplication of natural powers, that it is perfectly irreconcileable with sound physiology. Add to this, that of the phenomena adduced in its favour, no one is sufficiently consonant with the truth of nature to prove the hypothesis.

On the other hand, we have stronger and indubitable observations, which refute it directly and completely.

586. The less this hypothesis of evolution, as it is termed, is found consonant with fact and the rules of philosophizing, the more strongly does the opposite opinion recommend itself to our notice by its simplicity and correspondence with nature. It supposes not evolution of fictitious germina in conception, but a true and gradual formation of a new conception from the hitherto formless genital matter.

587. This has been variously described by physiologists, but the following I consider as the true account:

1. The matter of which organized bodies, and therefore the human frame is composed, differs from all other matter in this, that it alone is subject to the influence of the vital powers.

Nor can I sufficiently wonder how this eminent physiologist would reject, as almost absurd, the inosculation, properly so called, of the vessels of the chick with those of the yolk, while at the same time he admitted and defended a similar inosculation in the connexion of the human ovulum with the gravid uterus.

2. Among the orders of vital powers, one is eminently remarkable and the least disputable of all,—which, while it acts upon that matter hitherto shapeless but mature, imparts to it a *form* regular and definite, although varying according to the particular nature of the matter. To distinguish this vital power from the rest, permit me to designate it by the term,—*nisus formativus*.

3. The nisus formativus occurs to the *genital* matter, when mature, and committed to the uterus in a proper condition and under proper circumstances, lays in it the rudiments of conception, and gradually forms organs fitted for particular purposes, preserves this structure during life, by nourishing the body, and reproduces, as far as it can, any part accidentally mutilated*.

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* Here allow me to make three remarks :—

1. I have used the expression nisus formativus, merely to distinguish it from the other orders of vital powers, by no means to explain the cause of generation, which I consider equally involved in Cimmerian darkness as the cause of gravitation or attraction,—merely terms given to effects discovered, like the nisus formativus, a posteriori.

2. The word *nisus* I have adopted to express an energy truly vital, and to distinguish it as clearly as possible from powers merely mechanical, by which some physiologists formerly endeavoured to explain generation.

3. The point on which the whole of this doctrine respecting the nisus formativus turns, and which is alone sufficient to distinguish it from the vis plastica of the ancients, or the vis essentialis of Wolff, and similar hypotheses, is the union and intimate co-exertion of two distinct principles, in the evolution of the nature of organized bodies, of the *physico-mechanical*, with the purely *teleological*, —principles which have hitherto been adopted, but separately, by physiologists, in framing theories of generation.

588. I therefore think it very probable that those fluids which, during a successful coition, are thrown into the cavity of the uterus (527, 533, 551), require a certain period for becoming intimately mixed, acted upon, and matured; that, after this preparatory stage, the nisus formativus is excited in them, vivifying and shaping the hitherto shapeless spermatic matter partly into the beautiful containing ovulum, and partly into the contained embryo; and that this is the reason of our inability, notwithstanding the present perfection of optical instruments, to discover, during the first weeks after conception, any thing more than shapeless fluids, without the faintest trace of the form of an embryo, which, however, about the third month, suddenly becomes observable.

589. I should exceed the limits of these institutes, were I to adduce many of the arguments which may be drawn from facts, to illustrate, in my opinion, most clearly, the great influence of the nisus formativus in generation. I will, however, venture to mention, as briefly as possible, a few, whose weight will, on a little close reflection, be sufficiently evident.

590. Such, in the history of hybrid animals, is the singular experiment of impregnating those which are prolific, for many generations, with male semen of the same species, by means of which the form of the young hybrids becomes so progressively different from the original maternal configuration, as to approach more and more to that of the father, till, by a kind of arbitrary metamorphosis, it is absolutely converted into it.

591. From our knowledge of *monsters*, which, according to the hypothesis of evolution, are maintained and have pre-existed in the germs from the first creation, may be derived an important argument,—viz. that among cer-

tain *domestic* species of animals, and especially among sows, monstrosities are very common, while in the original wild variety they are extremely uncommon.

592. While the phenomena of *reproduction* are all much more explicable by the nisus formativus than by the pre-existence of germs for every part, some particular instance, (v. c. of the nails, which, after the loss of the first phalanx of the fingers have been known to be reproduced, on the neigbouring middle phalanx,) admit evidently of no other solution.

593. From an impartial view of each side of the question, it will clearly appear, that the defenders of the germs must allow to the male semen, not only an *exciting* power, as they do, but likewise great *formative* powers, and thus their doctrine stands in need of the assistance of the nisus formativus, while our explanation, on the contrary, is sufficient, without the aid of pre-existent germs, to explain the phenomena of generation. Nor can there be any reason for multiplying the *entia*, as they are called, unnecessarily.

SECT. XLI.

OF LABOUR AND ITS SEQUELÆ.

594. THE fœtus, formed by the powers just described, being now perfected, has to come into the world by means of *labour*.

595. This critical *period* occurs naturally (and physiology treats solely of natural occurrences) at the end of the tenth lunar month from conception, i. e. about the 39th or 40th week.

596. At that time, the woman is impelled to bring forth, by an absolute necessity, less under the influence of the will, than any other voluntary function (287).

597. Physiologists have differed in their explanations of the course of so determinate and sudden an event. After all, the *exciting* cause of labour must be ascribed to an eternal law of nature, hitherto equally inexplicable as many other similar *periodical* phenomena in nature; v. c. the metamorphosis of insects, the stages of exanthematic fevers, crises, &c. &c. nor has the mature ovum been inaptly compared, *ceteris paribus*, to fruit, which, when ripe, falls almost spontaneously to the ground, from the constriction of those vessels which previously conveyed its nourishment. And, in fact, it has been remarked, that

the human placenta, at the approach of labour, is contracted, and, as it were, prepared for its separation from the uterus.

What is usually urged respecting the utmost expansion of the uterus, and other similar excitements to labour, is refuted by many circumstances, and, among the rest, by the numerous examples of extra-uterine, whether tubal or ovarian conceptions, in which, at the expiration of ten months, the uterus, notwithstanding its vacuity, is seized with the customary, though indeed fruitless, pains.

598. Besides this exciting cause, other very powerful efficient causes are requisite, as must be manifest from the relation of the ovum to the uterus.

I am persuaded that the *proximate* and primary cause, is solely the *vita propria* of the uterus (42, 547).

Among the *remote*, the most important is the respiratory effort excited principally by the great connexion of the intercostal nerve with the rest of the nervous system.

599. I formerly noticed (582) that during the latter periods of pregnancy, the uterus somewhat subsided, by which circumstance the form of the abdomen is changed, and the inconveniences induced during advanced pregnancy in the function of respiration, are relieved. At the same time, the vaginal mucus (543) is secreted more abundantly, the vagina itself is relaxed, the columns of rugæ are almost obliterated, the labia pudendi swell; finally, near the approach of labour, the os uteri dilates into a circular opening.

600. The *phenomena* of labour generally observe a regular order of invasion and cessation, whence accou-

cheurs have divided them into *stages*, of which the moderns enumerate four, but define them variously.

601. In the first, the true pains occur, peculiar in their nature, proceeding from the loins downwards, in the direction of the uterus (recurring, at intervals, indeed during the whole of labour, with various degrees of violence and frequency), at first milder, when they are called *warning*, and the os uteri begins evidently to dilate.

602. In the second, the pains increasing, are called *preparing*, and from the effect of the respiratory organs, by means of a strong inspiration, a segment of the lower part of the membranes of the ovum is protruded through the uterine orifice into the vagina.

603. In the third, the pains becoming more excruciating, are called labour pains, and act with still more violence upon the uterus, which is driven downwards, and compressed against the fœtus, so that the protruded segment of membranes becomes extremely tense, is burst asunder, and the greater part of the liquor amnii escapes.

604. Finally, in the fourth and last stage, the pains becoming dreadfully violent and *agitating**, are accompanied with great exertions of the woman herself; frequently

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* Although even among my own countrywomen, the symptoms described under these four stages, vary greatly in violence and proportionate duration; nevertheless, however naturally they take place, they universally, (excepting some extremely rare cases,) so far surpass the pains experienced by domestic brutes in their labours, that I trust no one who has frequently witnessed labours in both, will doubt the immense difference between the two in this respect.

too with shivering, shrieking, tremor of the knees, &c. The head of the child, now on the verge of birth, penetrates, and the face first appears, the vextex usually adhering under the arch of the pubis, and the rest of the head in the mean time being farther propelled and revolving around the impacted vextex as around an axis; and thus the child comes into the world, in the midst of a red discharge, consisting of a second portion of the liquor amnii mixed with blood.

605. Soon after the expulsion of the child, the *after-labour* commences, attended with a painful though much less violent exertion, and followed by another hemorrhage from that part of the cavity of the womb to which the placenta had adhered by means of the decidua crassa*.

606. Immediately that both burthens are expelled, the uterus begins gradually to contract, until it acquires its original form, and very nearly its original size.

607. For about a week after labour, the *lochia* are discharged, for the most part, very similar to the catamenia, but rather more copious, especially if the mother does not suckle her offspring. About the sixth day, their

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* Nic. Mossam and all since his time, denominate this portion of the womb, during or shortly after pregnancy, *the cotyledons*, from the appearance observable in the gravid uterus of sheep or goats, to which such acetabula adhere, receiving what are called the glandular corpuscles of the chorion, corresponding with the fœtal portion of the human placenta.

Whatever was hollow, like an acetabulum, was called κοτυλη, by the ancients. Vide T. Cammerarii Comm. utriusque linguæ, 256, 384.

red colour becomes fainter, and afterwards is converted into white. At the same time the uterus is liberated from the ramenta of the decidua, and having thus completed the function of pregnancy, is again ready for menstruation or conception.

SECT. XLII.

OF THE MILK.

608. THE *breasts*, most sacred fountains, and, as Gellius Favorinus calls them, the educators of the human race, are intimately connected with the uterus in various ways. Both can scarcely be said to exist during infancy: at puberty, both begin to flourish,—when the catamenia appear, the breasts assume some degree of plumpness: from that period they undergo either simultaneous changes,—the breasts beginning to swell and secrete milk during the pregnancy of the womb; or alternate changes, —the catamenia ceasing while the child is suckled, or the lochia becoming copious if the child is not suckled. Finally, when old age creeps on, the function of each absolutely ceases,—when the catamenia disappear, both the uterus and the breasts become equally inert. I omit pathological phenomena; v. c. those which occur in irregular menstruation, leucorrhœa, after extirpation of the ovaria, and in other morbid affections.

609. If this intimate connexion is kept in view, we shall not be astonished that nearly every description of sympathy formerly mentioned (56) exists between these organs of the female thorax and abdomen.

610. The anastomatic sympathy, especially between the internal mammary and epigastric arteries, is considered of very great influence, but formerly was overrated. Its importance is evinced by the change which the epigastric experiences in its diameter during pregnancy and lactation.

611. Both the uterus and mammæ appear to have a kind of affinity for the chyle, observable in many diseases, and nearly always in new-born children.

612. The *breast* of women, belonging to the most characteristic marks of the human female, both by its form during the flower of age, and by the longer continuance of this form after the period of suckling, than occurs in any other female animal, is composed of a placentiform series of conglomerate glands, divided by numerous furrows into larger lobes, and buried in a mass of fat; the anterior part swells out particularly with a firmer description of fat over which the skin is exceedingly thin.

613. Each of these lobes is composed of still smaller lobes, and these of acini, as they are termed, to which the extreme radicles of the *lactiferous ducts* adhere, deriving a chylous fluid from the ultimate twigs of the internal mammary arteries.

614. These radicles gradually uniting, form large trunks, about fifteen in each breast. These are every where dilated into large sinuses, but have no true anastomosis with each other.

615. These trunks terminate in very delicate excretory canals, which are collected towards the centre, by means of cellular substance, into the *nipple*, which, being well supplied with blood-vessels and nerves, is capable of a curious erection on the approach of certain external stimuli.

616. The nipple is surrounded by the areola, which, as well as the nipple, is remarkable for the colour* of

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* In pregnant women, especially during the first pregnancy, the nipples are usually yellow. In the Samojede women, although virgins, Klingstaedt asserts that they are quite black. Mem. sur les Samojedes et les Lappons. p. 44.

the reticulum under the skin, and contains sebaceous follicles.

617. The secretion of the breast is the *milk*, well known in colour, watery, somewhat fatty, rather sweet, bland, resembling in all respects the milk of domestic animals, but subject to infinitely greater varieties in the proportion of its constituent parts, and far more difficult of coagulation, from the great quantity of salt which it contains, and affording no trace of volatile alkali.

618. When coagulated by means of alkohol, it discovers the same elements as the milk of other animals. Besides the *aqueous* halitus which it gives off when fresh and warm, the *serum* separating from the *caseous* part, contains sugar of milk, acetic acid mixed with phosphate of lime and of magnesia, and with oil and mucus. The butyraceous cream is said to consist of globules of various and inconstant size, their diameter ranging between $\frac{1}{2\,0\,0}$ and $\frac{1}{6\,0\,0}$ of a line.

619. The analogy between chyle and blood, and between both these fluids and milk, renders it probable that the milk is a kind of reduced chyle, again separated from the blood before its complete assimilation. This idea is strengthened by the existence in the milk of the particular qualities of food previously taken, and by the chylous appearance of the watery milk which trickles from the breasts during pregnancy and immediately after labour*.

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* Many arguments induce me to believe, that the lymph of the absorbents is of much importance to the secretion of milk. For instance, the swelling of the subaxillary glands almost always observable during the first months of pregnancy.

But especially the remarkable fact, that, in advanced pregnancy, when, from the size of the womb compressing the large and nu-

620. The reason why this bland nourishment of the fœtus becomes, by continued sucking, more thick and rich, is probably the abundance of lymphatics in the breasts. Those vessels continually absorb more of the serous portion of the milk, in proportion as its secretion is more copious and lasting, and by again pouring this portion into the mass of blood, promote the secretion (477): after ablactation they take up the residual milk, and mix it with the blood.

621. The milk is secreted in greatest quantity immediately after delivery; and, if the infant sucks, amounts to one or two pounds every twenty-four hours, until the menses, which usually cease during suckling, return.

Occasionally virgins, and new-born infants of either sex, nay even men, as well as the adult males of other mammalia, have been known to furnish milk.

622. The abundance of milk excites its *excretion*, and even causes it to flow spontaneously. But pressure, or the suction of the child, complete its discharge.

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merous lumbar plexuses of lymphatics the legs have swollen and this œdematous tumor so completely disappears immediately after labour that the calves of the legs hang almost flaccid from the lymph finding no impediment in the lumbar plexuses and rushing upwards, a more copious secretion of milk instantly ensues upon the progress of the lymph.

The momentary thirst (330) experienced on applying the child to the breast, from the absorption of fluid in the fauces, may be also mentioned.

SECT. XLIII.

OF THE DIFFERENCES IN THE SYSTEM BEFORE AND AFTER BIRTH.

623. FROM what has been said relatively to the functions of the fœtus still contained within its mother and immersed as it were in a warm bath, there must evidently be a considerable difference between its animal functions and those of the child which is born and capable of exerting its will. The chief points of difference I shall distinctly enumerate.

624. To begin with the blood and its motion, this fluid is remarkable both for being of a darker red, incapable of becoming florid on the contact of atmospheric air, and for coagulating less readily and perfectly than after birth. Its course too is very different in the fœtus, whose circulation is connected with the placenta, and who has never breathed, from its course after the cessation of this connexion with the mother, and after respiration has taken place.

625. First, the umbilical vein coming from the placenta, and penetrating the ring properly called umbilical, runs to the liver, and pours its blood into the sinus of the vena portæ, the branches of which remarkable vein distribute one portion through the liver, while the *ductus*

venosus ARANTII conveys the rest directly to the inferior vena cava.

Both canals,—the umbilical vein contained in the abdomen of the fœtus, and the venous duct, become closed after the division of the chord, and the former is converted into the round ligament of the liver.

626. The blood arriving at the right side of the heart, from the inferior cava, is in a great measure prevented from passing through the lungs, and is derived into the left or posterior auricle of the heart, by means of the Eustachian valve and the foramen ovale.

627. For, in the fœtus, over the opening of the inferior cava, there is extended a lunated valve, termed from its inventor, Eustachian, which usually disappears by degrees at puberty; but, in the fœtus, appears to direct the stream of blood coming from the abdomen towards an opening immediately to be mentioned, existing in the septum of the auricles.

628. This opening is denominated the *foramen ovale*, and is certainly the chief cause why the blood, which streams from the inferior cava, is poured into the left auricle, during the diastole of the auricles*. A falciform valve, placed over the foramen, prevents its return, and appears likewise to preclude its course into the left auricle, during the systole of the auricles. By means of this valve, the foramen generally becomes closed in early in-

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* For an account of the opinion of C. R. Wolff, who regards the foramen ovale as another mouth of the inferior cava, opening into the left auricle in the same manner as the mouth commonly known opens into the right. Vide Nov. Comment. acad. scient. Petropol. t. xx. 1775.

fancy, in proportion as the corresponding Eustachian valve decreases, and more or less disappears.

629. The blood, which, having entered the right auricle, passes from it into the right ventricle, is principally that portion which proceeds from the superior cava. It flows but in very small quantity into the lungs, while, from the right ventricle, which, in the fœtus, is remarkably thick and strong for this purpose, it pursues its course directly to the arch of the aorta, by means of the *ductus arteriosus*, which is, at it were, the chief branch of the pulmonary artery. A few weeks after birth, this duct becomes obstructed and converted into a kind of dense ligament.

630. The blood of the aorta, being destined to return, in a great measure, to the mother, enters the umbilical arteries, which pass out on each side of the urachus at the umbilical opening, and, after birth, likewise become imperforate chords.

631. As the function of the lungs scarcely exists in the fœtus, their appearance is extremely different from what it is after the commencement of respiration. They are proportionally much smaller, their colour is darker, their substance denser, consequently their specific gravity is greater, so that while recent and sound they sink in water, while, after birth, they, cæteris paribus, swim upon its surface. The right lung has the peculiarity of dilating during the first inspiration rather sooner than the left. The other circumstances attending the commencement of respiration were described in the section upon that function.

632. From our remarks upon the nutrition of the fœtus, it is clear that its alimentary tube and chylopoietic system must be very peculiar. Thus, v. c. in an embryo a few

months old, the large intestines very nearly resemble the small; but during the latter half of pregnancy, they increase, and really deserve the epithet by which they are commonly distinguished.

633. The *meconium* is a saburra, of a brownish green colour, formed evidently from the secreted fluids of the fœtus, and chiefly from its bile, because it is first observed at the period corresponding to the first secretion of the bile; and in monstrous cases, where the liver has been absent, no meconium, but merely a small quantity of colourless mucus, has been found in the intestines.

634. The *cæcum* is extremely different in the fœtus, and continued straight from the appendix vermi-formis.

635. Other similar differences we have already spoken of, and shall now pass over. Such are the *urachus*, the *membrana pupillaris*, the descent of the testes in the male.

Some will be treated more properly in the next section. Others, of little moment, I shall entirely omit.

636. This is a favourable opportunity for briefly noticing some remarkable parts, which are out of all proportion larger in the fœtus, and appear to serve important purposes in its economy, although their true and principal design deserves still further investigation. They are usually styled glands, but their parenchyma is very abhorrent from true glandular structure, nor has any vestige of an excreting duct been hitherto discovered in them. They are the thyreoid, the thymus, and the supra-renal glands*.

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* Vide F. Mechel's Abhandlungen aus der. Menschlichen u Vergleichenden Anatomie. Hal. 1806. 8vo. He makes it probable that these three organs contribute to the chemical functions of the nervous and hepatic systems, and thus diminish the gravity of hydrogen and carbon.

637. The *thyreoid gland* is fixed upon the cartilage of the same name belonging to the larynx, has two lobes, is, as it were, lunated, and full not only of blood, in which it abounds in the fœtus, but of lymphatic fluid, and becomes, as age advances, gradually less juicy.

638. The *thymus* is a white and very tender structure, likewise bilobular, occasionally containing a remarkable cavity, placed under the superior part of the middle of the sternum, always ascending as far as the neck on each side, of extremely great proportionate size in the fœtus, abounding in a milky fluid, becoming gradually absorbed in youth, and frequently disappearing altogether in old age.

639. The *supra-renal glands*, called also renes succenturiati and capsulæ atrabiliariæ, lie under the diaphragm on the upper margin of the kidneys, from which, in the adult, they are rather more distant, being proportionally smaller. They are full of a dark fluid, of a more reddish hue in the fœtus than in the adult.

SECT. XLIV.

OF THE GROWTH, STATIONARY CONDITION, AND DECREASE OF MAN.

640. NOTHING more remains at present than to survey the natural course of the life of man, whose animal functions we have thus arranged in classes, and examined individually, and to accompany him through his principal epochs from his birth to his grave.

641. The *commencement of formation* appears to happen about the third week from conception (569), and genuine *blood* is first observable about the fourth, the life of the fœtus at this period being extremely faint, and almost merely that of a vegetable; the *motion of the heart* (98), which has under fortunate circumstances been observable in the human embryo, though long since detected by Aristotle in the incubated egg, has ever since his time been called the *punctum saliens*.

The original form of the embryo is simple, and, like that of a grub, wonderfully different from the perfect conformation of the human frame, which deserves to be regarded as the grandest effect of the nisus formativus, and at which it arrives by gradual changes, or if I may so

speak, metamorphoses from a more simple to a more perfect form.*

642. The formation of human bone† begins, if I am not mistaken, in the seventh or eighth week. First of all, the osseous fluid forms its nuclei in the clavicles, ribs, vertebræ, the large cylindrical bones of the extremities, the lower jaw, and some other bones of the face, in the delicate reticulum of some flat bones of the skull,—of the frontal and occipital, but less early in the parietal. In general, the growth of the embryo, and indeed of the

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* Hence, as I have remarked in another place, (—Nova Litteraria Goettingensia, a 1808, p. 1386), human monsters are sometimes met with, resembling the form of brutes so strongly, that the nisus formativus, having been disturbed and obstructed from some cause or other, could not have reached the highest pitch of the human form, but rested at a lower point, and produced a bestial shape. On the contrary, I have never once found among brutes a true example of monstrosity, which, by a bound of the nisus formativus, bore any analogy to the human figure.

† I say of *human* bone; for in the incubated chick, it begins much later,—on the ninth day, which corresponds with the seventeenth week of human pregnancy.

Observations, therefore, made on the incubated chick, must *not be* applied to the formation of the human embryo,—an error committed by the great Haller himself, who clearly asserted that, *what he had demonstrated in regard to the incubated chick, was equally applicable to other classes of animals and to man himself.*

This opinion gained so much ground subsequently, that some physicians who endeavoured to settle the forensic disputes respecting premature labour, adduced their arguments from a hasty comparison of the periods of this incubation, with those of human pregnancy. Vide, v. c. Hug. Marreti's Consultation au Sujet d'un enfant, &c. Divion. 1768.

human being after birth, is more rapid as the age is less, and v. v.

643. About the middle of pregnancy, certain fluids begin to be secreted, as the *fat* and *bile*. In the course of the seventh month, all the organs of the vital, natural, and animal functions have made such progress, that if the child happens to be born at this period, it is called, in a common acceptation of the word, *vital*, and regarded as a member of society.

644. In the fœtus, near its full growth, not only is the skin covered by a caseous matter, but delicate hair appears upon the head, and little nails become visible; the *membrana pupillaris* splits; the cartilaginous external ear becomes more firm and elastic; and in the male the *testes* descend. (510, et seq.)

645. Near the end of the tenth lunar month, the child, when born, (595), undergoes besides those important changes formerly described at large, other changes in its *external* appearance; v. c. the down which covered its face at birth, gradually disappears, the wrinkles are obliterated, the anus becomes concealed between the swelling nates, &c.

646. By degrees the infant learns to employ its mental faculties of perception, attention, reminiscence, inclination, &c. whence, even in the early months, it dreams, &c.

647. The organs of the *external senses* are gradually evolved and perfected, as the external ear, the internal nares, the coverings of the eyes, viz. the supra-orbital arches, the eyebrows, &c.

468. The bones of the skull unite more firmly, the *fonticuli* are by degrees filled up; and about eight weeks after birth, *dentition* commences.

649. At this period the child is ready to be weaned, his teeth being able to manducate solid food, and not intended to injure the mother's breast.

650. About the end of the first year, it learns to rest upon its feet, and *stand erect*,—the highest characteristic of the human body.

651. The child now weaned from its mother's breast, and capable of using its feet, improves and acquires more voluntary power daily. Another grand privilege of the human race is bestowed upon it,—the use of speech,---the mind beginning to pronounce, by means of the tongue, the ideas with which it is familiar.

652. The twenty milk teeth by degrees fall out after the seventh year, and a *second dentition* produces, in the course of years, thirty-two permanent teeth.

653. During infancy, *memory* is more vigorous than the other faculties of the mind, and by far most powerful in receiving tenaciously the signs of objects: after the fifteenth year, the fire of imagination burns most strongly.

654. This more lively state of the imagination occurs very opportunely at *puberty*, when the body undergoing various remarkable changes, is being gradually prepared for the exercise of the sexual functions.

655. Immediately after the period when the breasts of the adolescent girl have begun to swell, the chin of the boy is covered with down, and the phenomena of puberty manifest themselvs in either sex. The girl begins to menstruate, (354),---an important change in the female economy, accompanied, among other circumstances, nearly always by an increased brightnesss of the eyes, redness of the lips, and more evident sensible qualities of the perspiration. The boy secretes genuine *semen* (527), and at

the same time, the *beard** grows more abundantly, and the *voice* becomes remarkably grave.

By the spontaneous internal voice of nature, as it were, the *sexual instinct* (71) is now for the first time excited, and man, being in the flower of his age, is capable of sexual connexion.

656. The *period* of puberty cannot be exactly defined, it varies with climate and temperament,† but is universally more early in the female; so that in our climate, girls arrive at puberty about the fifteenth year, and young men, on the contrary, about the twentieth.

657. Soon after this, *growth* terminates; at various periods, however, in different individuals, families, and climates.‡

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* The fabulous report, even at this day prevalent, respecting the want of beard among some American nations, I refuted by a host of witnesses in the Gotting. Magaz. ann. ii. p. vi. p. 418 et seq. For I have adduced instances from the whole of America, both of nations who allow their beard to grow, at least, in parts; and of others, who, upon indubitable authority, pluck out their beard by peculiar instruments.

† I have inserted in the Bibl. Medic. vol. i. p. 558 et seq. an account communicated to me by G. E. ab. Haller, of procreation in a Swiss girl only nine years of age.

‡ For man has no peculiar privilege of not experiencing the effects of climate in common with other organized bodies, which are commonly known to arrive at their growth much later, cæteris paribus, in cold than in warm climates.

As to the giants of Patagonia, and the dwarfs of Madagascar, mentioned by Commerson, I have reduced the exaggerated accounts of the former to a true statement, and have shewn that the latter are diseased Cretins, in my Treatise de Gen. hum. var. nativ.

658. The *epiphyses* of the bones hitherto distinct from their diaphyses, now become intimately united, and, as it were, confounded with them.

659. At *manhood*,—the longer and more excellent period of human existence, life is, with respect to the corporeal functions, at the highest pitch (82), or, in other words, these functions are performed with the greatest *vigour* and *constancy*; in regard to the mental functions, the grand prerogative of mature *judgment* is now afforded.

660. The approach of *old age* is announced in women, by the cessation of the catamenia (556), and not unfrequently by an appearance of beard upon the chin;* in men, by less alacrity to copulate: in both, by a *senile* dryness, and a gradually manifested *decrease* of vital energy.

661. Lastly, the frigid condition of old age, is accompanied by an increasing dulness of both the external and internal senses, a necessity for longer sleep, and a torpor of all the functions of the animal economy. The hairs grow white, and partly fall off. The teeth gradually drop out. The neck is no longer able to give due support to the head, nor the legs to the body. Even the bones themselves—the props of the machine—in a manner waste away, &c.

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* Vide J. Burlin de fæminis ex suppressione mensium barbatis. Altæf. 1664, 4to. A remarkable phenomenon, deserving further investigation, and analogous to a change frequently remarked in female birds, which, after ceasing to lay eggs, lose the feathers peculiar to their sex, and acquire those characteristic of the male. Examples of this occur in the columba œnas, phasianus colchicus, pavo cristatus, otis tarda, pipra rupicola, anas boschas, &c.

662. Thus we are conducted to the ultimate line of physiology,—to death without disease, to the senile εὐθανασια, which it is the first and last object of medicine to procure, and of which the cause must be self-evident from our preceding account of the animal economy.

663. The phenomena of a moribund person are coldness of the extremities, loss of brilliancy in the eyes, smallness and slowness of the pulse which more and more frequently intermits, and infrequency of respiration which at length terminates for ever by a deep expiration.

In the dissection of other moribund mammalia, the struggle of the heart may be perceived; the right auricle and ventricle of which are well known to live rather longer than the left, (117).

664. Death is manifested by the coldness and rigidity of the body, the flaccidity of the cornea, the open state of the anus, the lividness of the back, the depression and flatness of the loins (52, *Note)*, and above all, by an odour truly cadaverous. If these *collective* marks are present, there can be no room for the complaint of Pliny, that one ought not to believe even a dead man.

665. It is scarcely possible to define the natural period of life, or, as it may be termed, the more frequent and regular limit of advanced old age. But by an accurate examination of numerous bills of mortality, I have ascertained a remarkable fact,—that a very large proportion of Europeans reach their eighty-fourth year, while, on the contrary, few exceed it.

666. On the whole, notwithstanding the weakness of children, the intemperance of adults, the violence of diseases, the fatality of accidents, and many other circumstances, prevent more than perhaps seventy-eight persons out of a thousand from dying of old age, without disease,

nevertheless, if *human longevity* be compared, cæteris paribus, with the duration of the life of any other animal among the mammalia, we shall find that of all the sophistical whinings about the misery of human life, no one is more unfounded than that which is commonly made respecting the shortness of its duration.

FINIS.

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