XXIII. *On the Blood-Proper and Chylaqueous Fluid of Invertebrate Animals. By* Thomas Williams, *M.D. Lond., Extra Licentiate of the Royal College of Physicians, and formerly Demonstrator on Structural Anatomy at Guy's Hospital. Communicated by* Thomas Bell, *Sec. R.S.*

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In the following memoir, I propose to submit to the Royal Society a collection of facts observed with repeated and scrupulous care, which I trust will suffice to establish the propositions, viz. that in invertebrate animals there exist two distinct nutritious fluids, dissimilar in their anatomical relations, and different in their chemical and vital compositions; that, in the animal series, a gradation from the simple to the complex is observed in the *fluid* as well as in the solid elements of the organism; that these two constituent parts of the animal body bear towards each other, whether in simplicity or complexity, a constant and direct proportion; that the true blood-system does not begin at the beginning of the animal series, but that it arises out of (*what in this memoir will be called*) the chylaqueous fluid, of which the blood-proper is the perfected evolution; that the chylaqueous fluid is as much less vitalized than the true-blood, as the solid structures of the animals in which the former exists are less complex than the analogous parts of those in which the latter is found; that the containing system of the blood-proper is distinguished, with the single exception of that of the Echinodermata, by the absence of vibratile cilia from its *internal* lining membrane, while that of the chylaqueous fluid is provided in the same situations, almost invariably, with these motive organules; that the contents of the former system are propelled by the contractile force of its muscular parietes, while those of the latter are circulated chiefly by ciliary vibration; that below the Echinodermata the blood-proper is wholly supplanted by the chylaqueous fluid; that above the Annelida the latter fluid in the adult animal is superseded by the true-blood; that in the Echinoderms and Annelids these two systems of nutrient fluids co-exist, bearing always to each other, in the same individual, an inverse quantitative proportion; that in the Mollusca these two are united into a single system, in which the essential characteristics of both are legible; and that these facts, hitherto unrecognised in their physiological connection, and unappreciated in their separate meaning, are calculated to elucidate, with new clearness, the processes of digestion, sanguification, and respiration, more especially in the lowest classes of invertebrate animals; and finally, that they suggest inquiry from novel points of view, into several important questions in zoo-chemistry.

In this communication it is my desire to restrict myself chiefly to the demonstration of the corpuscular or morphotic elements of the fluids, postponing to a future occasion the attempt to apply the results of these researches to the problems in comparative physiology which they promise, satisfactorily, to resolve.

As far as my inquiries into the historical literature of this subject have extended, I may affirm that no systematic definition of the real nature of the circulating fluids, in the lowest orders of animals, has ever yet been attempted in physiological science. The true mechanism of nutrition in zoophytic, radiate and annulose organisms, has never yet, at the hands of zoo-chemists, received a satisfactory explanation. The organic fluids have been subjected in no one of their characters to a full and adequate investigation.

They have been permitted to remain, up to this time, almost entirely undescribed and uncomprehended.

To these condemnatory observations, exception must be made in favour first of AGASSIZ and MILNE-EDWARDS. Obscure hints, tending to the right track of study, have been thrown out by the former naturalist, and by the latter, certain generalized views have been propounded which serve only to indicate the correct direction of inquiry. AGASSIZ* remarks, "Instead of the three conditions of chyme, chyle, and blood, which the circulating fluids of the Vertebrata undergo, the blood of that class of the Invertebrata which I have particularly studied, the Annelida, is, according to WAGNER, simple chyle, coloured chyle; the receptacles of chyle in different parts of the body are true lymphatic hearts, like those found in the Vertebrata: this kind of circulation is found in the Articulata and Mollusks, with few exceptions, some Echinoderms, &c. In the Medusæ and Polyps, instead of chyle, chyme mixed with water is circulated: this circulation is found in some Mollusks and intestinal worms; it may be seen plainly in *Beroë*." It will be subsequently shown that these boldly propounded generalities seldom approach the truth of nature as established by practical observation.

The admirable researches of MILNE-EDWARDS† were chiefly directed towards the determination of the *mechanism* of the circulation, rather than to the composition of the fluids. His inquiries were principally limited to the Annelida, Mollusca and Crustacea. With him originated the generalization, that "in no Mollusk does there exist a closed system of blood-vessels; that in the Bryozoa or Polyzoa, the initiatory class to the Mollusca, neither heart, arteries nor veins are found, the nutrient fluid being contained in the great visceral cavity, in which the organs of digestion are suspended; that in the Molluscoid Tunicata a heart and a system of blood-vessels exist only in the branchial portion of the body, the abdominal or visceral circulation being conducted by means of cells or lacunæ of uncertain direction and without any

* SILLIMAN's American Journal for July 1850.

† Annales des Sciences Naturelles, Série 3me. t. iii. 280 (1845).

definable walls; and that in the Gasteropods and Cephalopods the visceral or peritoneal cavity forms a part of the circle of the blood's movement*."

The observations of MILNE-EDWARDS have been repeated by VALENCIENNES†, by Professor Owen‡ on the Brachiopods, by E. BLANCHARD among the Entozoa§, by QUATREFAGES and others. It has been doubted however by HANCOCK and EMBLETON whether the views of MILNE-EDWARDS with reference to the lacunose character of the peripheral segment of the circulating system in Mollusca, express the true type of the circulation in the Nudibranchia.

While acknowledging the extreme interest of the discoveries accomplished by the latter distinguished men, they will be found in every instance to be limited merely to "the system of conduits" through which the blood describes its circulation, distinct therefore in object and subject from those inquiries which are specially addressed to a consideration of the characters and relations of the nutrient fluids themselves, and which it is the purport of this memoir to record.

The *blood itself* was made the subject of more special remark by Sir E. HOME‖, who states that the blood of the Teredines is red, and that of the Planorbis purple. MILNE-EDWARDS says that in the vicinity of Palermo he discovered an Ascidian with red blood¶. The blood in Lamellibranchiate Mollusks has been made the subject of observation by Mr. GARNER**, with whose results, those stated in this paper will be found little to coincide.

LISTER proved that the blood of the Snail was coagulable††, and that that of the Ascidiæ contained globules. The conclusions of LISTER were confirmed by PREVOST and DUMAS‡‡, by whom it was supposed to have been shown that the globules in the blood of the Snail have a diameter one-third greater than those of man and quadrupeds.

POLI§§ has observed, "si tamen in bono microscopio examinetur, id est, syphone

* "Chez les Mollusques, de même que chez les Crustacés, une portion plus ou moins considérable du cercle parcouru par le sang en mouvement est toujours constituée par les lacunes ou espaces interorganiques; jamais ce liquide ne se trouve emprisonné, comme on le supposait, dans un système clos et complet de vaisseaux à parois propres; quelquefois il n'existe, pour une portion considérable du corps, ni artères ni veines, d'autres fois les artères portent le sang partout où il y a vie à entretenir, mais il n'y a pas de veines pour assurer le retour du fluide nourricier qui s'épanche dans les lacunes comprises entre les diverses parties solides de l'organisation; d'autres fois encore, l'appareil de la circulation se perfectionne davantage, car il existe des veines aussi bien que des artères dans une portion plus ou moins grande du corps; mais ces veines ne suffisent jamais pour compléter le cercle que le fluide nourricier doit parcourir, et la cavité abdominale ou péritonéale joue toujours le rôle d'un reservoir sanguin aussi bien que d'une chambre viscerale."—*Op. cit.*

† Nouvelles observations sur la constitution de l'appareil circulatoire chez les Mollusques, par MILNE-EDWARDS et VALENCIENNES.—*Ibid.* p. 307.

‡ Lettre sur l'appareil de la circulation chez les Mollusques de la classe des Brachiopodes; addressé à MILNE-EDWARDS par M. R. OWEN.

§ Annales des Sciences Naturelles, 3me sér. tom. iv.

‖ Comparative Anatomy, vol. i. p. 32.

¶ Elem. Zool. p. 18; and Mag. and Ann. Nat. Hist. vol. xv. 69.

** CHARLESWORTH's Magazine, Nat. Hist. vol. iii. p. 168.

†† Philosophical Transactions for 1834, p. 380.

‡‡ BOSTOCK's Physiology, vol. ii. p. 200.

§§ Exert. Anat. de coch. p. 95.

capillari vitreo, venæ alicui intruso, globulos opacos vere orbiculares haud paucos videbis; ac sanguineos nostros globulos magnitudine plurimum excedentes. Hi vero globuli ut præ sanguinis globulis pauci sunt, ita aqua quædam limpida innatant, et paulatim præ gravitate ad unum syphonem descendunt. Idem quoque experimentum de succo vitali in cochleis fluviatilibus feci; idemque coagulum sub-cæruleum, igni admotus, dedit." Iron and manganese have been detected by ERMAN in the blood of *Helix Pomatia* and *Planorbis corneus*.

To the historical references formerly given, it must be added that, more recently, two elaborate memoirs, "On the Blood-corpuscle considered in its different Phases of Development in the Animal Series," have been published in the Philosophical Transactions (1846), of which one relates exclusively to the blood of invertebrate animals. Emanating from a physiologist so distinguished as Mr. T. WHARTON JONES, these memoirs are entitled to the highest consideration. Although confined "to the more readily procurable examples of the divisions Annulosa and Mollusca," those on the Crustacea and Insects excepted, in no instance have I been able to verify the observations of this author.

In their most recent communication to the Royal Society*, ALDER and HANCOCK adduce additional facts corroborative of their former conclusions. They maintain "that in the Mollusks there is a triple circulation: first, the systemic, in which the blood propelled along the arteries to the viscera and foot is returned, with the exception of that from the liver-mass, to the heart through the skin; there it becomes partially aërated, the skin being provided with vibratile cilia, and otherwise adapted as an instrument of respiration; second, the portal, in which venous blood from the system is driven by a special heart to the renal and hepatic organs, and probably to the ovarium, where it escapes, doubly venous, with the rest of the blood which has been supplied to these organs from the aorta, and which is therefore only singly venous, to the branchiæ; third, the branchial circulation, in which flows only the more deteriorated blood brought by the hepatic vein, but in which also that blood undergoes the highest degree of purification capable of being effected in the economy, namely, in the special organ of respiration. This triple circulation has not yet, as far as the authors are aware, been described in the Molluscan Sub-kingdom. Since the blood in *Doris* is returned to the heart in a state of partial aëration, it is clear, they say, that this animal is, in this respect, on a par with the higher crustaceans; and since the blood arrives at the heart in the same condition, according to the researches of GARNER and MILNE-EDWARDS, in *Ostrea* and *Pinna*, the great *Triton* of the Mediterranean, *Haliotis*, *Patella* and *Helix*, it can scarcely be doubted that this arrangement will be found throughout all the Mollusca."

Elaborate as these admirable inquiries deserve to be characterized, they do not affect the truth of the leading proposition of MILNE-EDWARDS, that, viz. the visceral cavity constitutes a part of, and is an open communication with, the channels of the

* "On the Anatomy of *Doris*," Proceedings of the Royal Society, March 4, 1852.

circulation. Mr. Hancock and Dr. Embleton have shown that collateral *segments* of the circulation undergo a special elaboration for special or local purposes. They do not however *demonstrate* in any part of the blood's circuit a peripheral capillary system. They only state that "the existence of true capillaries in the liver-mass seems probable." In further elucidation of the tendency to special development in particular portions of the circulating system of mollusks, I have lately proved that the branchial capillaries in both the univalve and bivalve orders conform with singular constancy to one type of subdivision. The vessels are always parallel, never reticulate. These observations support the proposition formerly stated, that in the Mollusca the circulating system is really a product of the fusion of the chylaqueous system into that of the blood, properly so called. In a letter addressed to M. Milne-Edwards, Mr. Huxley observes, after an examination of the circulation of the blood in the genera *Firole* and *Atlante*, "J'ai obtenu ainsi une confirmation entière de vos vues relatives à la manière dont cette fonction s'exerce chez les Mollusques. ... Il n'existe point de veines quelconques ... Je suis porté à croire que l'absence plus ou moins complète de la portion veineuse du système vasculaire, loin d'être un cas exceptionnel, est l'état normal dans la plupart des classes de la grande division des animaux sans vertèbres*." It is however to the 'Mémoire' of M. Quatrefages, "Sur la cavité générale du corps des Invertébrés," *Annal. des Sciences Nat.* 1850, that, in this historical summary, special attention is invited. In this excellent essay M. Quatrefages first describes "la cavité générale du corps" as beginning with the Hydræ and Actiniæ, and closes the survey with the Mammalia, the serous cavities of which he likens to the visceral cavity of the body as it is found to exist in the Invertebrata. In the mere description of 'the cavity' there is no novelty. To all comparative anatomists for half a century *the existence* of the visceral cavity in the several classes of the Invertebrata has been familiar. To every observer it has long been well known that this cavity in *all* classes was occupied by *a fluid*. On *this* ground therefore no modern anatomist is entitled to the credit of discovery. In the year 1741, Trembley *saw* and accurately described the movement of a corpusculated fluid in the perigastric cavity and *tentacles* of the 'Polype à Panache.' But in the memoir "Sur la cavité générale du corps des Invertébrés," M. Quatrefages has sagaciously projected certain generalized views with regard to the possible functions devolving upon the fluid contained in this cavity, which to a limited extent run parallel with the conclusions which in this paper I have endeavoured to establish. It will however be readily seen by any one who will peruse the two essays with a view to a comparison, that they differ essentially in subject and object. M. Quatrefages' chief aim is to define the visceral cavity; he adds only a few *general* observations with reference to the physiological relations and functions of the fluid contents. He has not attempted to resolve the problem of its histological characters. His conclusions

* Observations sur la circulation du sang chez les Mollusques, des genres Firole et Atlante, Ann. des Sc. 1850.

are not based upon observed facts, but upon general views. He makes no allusion whatever to the relations which subsist between the chylaqueous system and that of the true blood; he has not defined the difference in the mechanism of solid nutrition as it occurs respectively under the agency of these two orders of fluids. M. QUATREFAGES has seized *no one* clue to the demonstration of the capital law of structure, viz. that the system of the blood-proper *only first appears* in the series at the Echinodermata. Unguided by this great and novel principle, he could not perceive that a blood-proper system could not exist, as it was not required *below the Echinodermata.* He affords no proof of having known that the chylaqueous system of fluid is governed physiologically and chemically by laws distinct from, though not less definite than those which regulate that of the true blood. He has accumulated *no* individual observations illustrative of the histological characters of the morphotic elements, either of the chylaqueous fluid, or the true blood. M. QUATREFAGES appears also to have been totally unacquainted with the interesting fact announced in this paper, that in histological structure, the corpuscles of the chylaqueous fluid are as *definite* and constant as those of the blood of the higher animals. It thus appears that, although the views of M. QUATREFAGES and those advocated in this paper proceed for a short distance in parallelism, they soon diverge towards two very different destinations*.

* Having stated in the text, in general terms, the most prominent features which distinguish the admirable memoir of M. QUATREFAGES from this paper, I am here desirous that this meritorious observer should speak for himself, and that my observations (submitted to the Royal Society six months before the advantage occurred to me of perusing the original memoir of M. QUATREFAGES) should be fortified and justified by the independent researches of one so much better known to European science. I only cite so much of the memoir of M. QUATREFAGES as really bears upon the subject of this paper. I quote *entire* his observations on the microscopic examination "*du liquide de la cavité générale*:—" Chez les Invertébrés, dont la cavité générale communique avec le tube digestif, le liquide que renferme cette cavité est toujours composé d'eau tenant en suspension des particules très ténues provenant des aliments. Chez les Mollusques, les Insectes, les Crustacés dont la cavité générale communique avec l'appareil circulatoire, le sang s'épanche librement dans cette cavité. Je l'ai généralement trouvé composé d'un liquide incolore, charriant des granulations irrégulières, transparentes, sans couleur, et qui semblaient assez souvent résulter de la soudure fortuite de granulations plus petites. On sait, du reste, que la description que je donne ici ne s'applique pas à tous Mollusques. Depuis longtemps on a signalé la couleur rouge violacée du sang du Planorbe corné. J'ai retrouvé quelque chose d'analogue dans le Planorbe imbriqué. Cette espèce est d'autant meilleure à signaler, que la transparence de sa coquille permet de l'observer sur le vivant. Enfin, une des exceptions les plus remarquables à citer a été découverte par M. EDWARDS. Ce naturaliste a trouvé en Sicile une Ascidie dont le sang, à la vue simple, est d'un beau rouge. Au microscope, on reconnaît que cette couleur est due à des globules framboisés, très réguliers, nageant dans un liquide incolore. Chez les Annelés, dont la cavité générale est close, j'ai également trouvé presque toujours cette cavité remplie par un liquide incolore, tenant en suspension des granulations irrégulières de forme et de volume très variables, également transparentes et sans couleur, mais réfractant la lumière avec beaucoup plus d'energie que le liquide ambiant; toutefois j'ai déjà fait connaître quelques exceptions, entre autres dans le mémoire sur la famille des Némertiens et dans une note sur le vaisseau dorsal des Insectes. Mes observations ont porté principalement sur les Annélides. Dans l'immense majorité des cas, ce que j'ai vu chez elles s'accorde avec la description générale que je viens de donner; pourtant j'ai encore ici des exceptions à signaler. Chez la Polynoé lisse, le liquide dont nous parlons charrie des globules ovalaires, aplatis, incolores, présentant l'aspect d'une substance homogène réfractant la lumière à peu près comme le liquide ambiant, et renfermant un noyau plus réfringent.

The preceding historical allusions, summary and brief though they be, will suffice to present an outlined view of the actual state of knowledge on the subject to which this memoir is dedicated.

In the account, now to be offered, of the nutrient fluids in the leading classes of invertebrate animals, it will be indispensable to the full development of the subject, that under each head a slight sketch be premised of the anatomical relations subsisting between these fluids and the digestive and respiratory organs. These references however will be compressed to the utmost brevity.

In the distribution of the materials, it seems preferable to begin with the lowest and simplest organisms.

Porifera.—In the sponge, the *fluid blastema*, formed directly out of the constituent

Ces globules sont souvent irréguliers ; ils ont environ $\frac{1}{32}$ de millimètre de diamètre longitudinal sur $\frac{1}{50}$ à $\frac{1}{40}$ de millimètre de diamètre transversal. Quant au noyau, il est sphérique, et son diamètre varie de $\frac{1}{70}$ à $\frac{1}{260}$ de millimètre environ. Parmi les Apneumées, qui déjà nous ont présenté des particularités organiques si curieuses, j'ai rencontré une espèce chez laquelle j'ai trouvé le liquide de la cavité générale coloré. A la simple vue, il est d'un beau rouge légèrement orangé ; lorsqu'on l'examine au microscope, on reconnaît que cette coloration est due à des globules très nombreux, très réguliers, présentant la forme que j'ai reproduite ici, c'est-a-dire celle de petits disques circulaires assez profondément excavés sur une de leurs faces (pl. 5. fig. 12, *op. cit.*), ce qui pourrait induire en erreur au premier coup d'œil, et faire croire à l'existence d'un noyau. Par transparence, ces globules paraissent jaunâtres. Leur diamètre est de $\frac{1}{75}$ de millimètre.

"Chez certains Siponcles, on trouve, dans la cavité générale, un liquide parfois tellement chargé de granulations, qu'il en est comme trouble. Dans une espèce très petite et assez transparente de nos côtes, j'ai pu constater sur le vivant que ces granules étaient framboisés, sphériques, et d'un diamètre à peu près constant. Ils sont d'ailleurs incolores. Chez certains autres Annelés de petite taille, chez les Rotateurs, par exemple, le liquide de la cavité générale ne présente que des granulations très rares, ou même n'en présente pas du tout. Une fort grande espèce de Notommate que je rencontrai au printemps, aux environs de Paris, m'a présenté, sous ce rapport, une exception : le liquide de la cavité générale contenait presque autant de granulations que celui de certaines Annélides." The preceding passage includes ALL the results which M. QUATREFAGES has given of "the microscopic examination of the liquid of the general cavity !"

Marvellously scanty as these results appear to me when estimated as the *data* on which he rests his conclusions, they will be found utterly irreconcileable with those (stated in the text) at which I have arrived from an examination of the fluids of *the same* animals.

Under the head of the "Nature du liquide de la cavité générale du corps dans les divers groupes d'invertébrés," M. QUATREFAGES remarks, "Le rôle joué par l'eau, qui lave en quelque sorte le tube alimentaire des Actiniaires et entraîne en passant tous les principes solubles des aliments digérés, est trop évident pour qu'il soit nécessaire d'insister sur ce point. Cette eau modifie, par son séjour dans la cavité générale, de plus en plus sa composition : elle s'animalise pour ainsi dire et forme dans la cavité générale du corps une sorte de bain nourricier, dans lequel plongent tous les organes. Qu'il existe ou qu'il n'existe pas chez ces animaux d'appareil vasculaire renfermant l'équivalent du sang proprement dit, cette eau n'en contribue pas moins d'une façon essentielle à la nutrition. De plus, quand elle est expulsée par les contractions de l'animal, elle entraîne avec elle les résidus de la digestion et les principes rejetés par l'organisme. Chez les Invertébrés dont la cavité générale sert en quelque sorte de carrefour aux appareils artériels et veineux, il est clair que le liquide de la cavité est essentiellement l'agent immédiat de la nutrition. Il n'est autre chose que le sang lui-même, qui pendant son séjour dans cette cavité, s'est enrichi de principes réparateurs venus soit de l'intestin, soit de la surface de tous les organes internes." Here M. QUATREFAGES adds a note, in which he admits as not improbable, "l'existence dans les Actinies d'un véritable système vasculaire indépendant de la cavité générale du corps," as described by SPIX

elements of the surrounding water, is contained in part in the interior of, and in part between, the cells of the gelatinous cortex*. I have proved that this fluid, which is the true blood of the sponge, is composed of a mixture of salt water and albumen. The *most* organized is that contained *in* the cells of the gelatinous cortex, the *least* is that *between* the cells. These cells actually vitalize and organize the elements of the aërated water. The sponge presents the *first* and simplest problem in zoo-chemistry†.

Polypifera.—In *all* Polypes the space between the stomach and integuments is filled with a corpusculated, organic fluid, varying in different species, moving to and fro under muscular or ciliary agency. It is principally composed of sea-water, which, in passing through the stomach, blends with the secretions of this organ, and then enters the visceral cavity, where it acquires those vital and chemical properties which fit it to nourish the solids of the body. In the hydraform and actiniform groups it has not yet been proved that the stomach opens directly into the visceral cavity. The tentacles in some species are undoubtedly perforated at their distal ends, in order to admit the surrounding water immediately into this cavity, where it admingles with the product of digestion, and undergoes, *thus directly*, the process of *organic* assimilation. In several small and transparent species of Actiniæ, I have lately *seen*, with perfect distinctness, the motion of the perigastric fluid by its corpuscles, and proved that the tentacles are *im*perforate at their distal extremities. In the composite forms of Polypes the bottom of the stomach communicates freely with the interior of the polypidom, as in *Campanularia* and *Alcyonidium*. This fluid in all zoophytes penetrates into all the appendages and recesses of the body. It is, in

in the *Actinia* and by WILL in *Alcyon Palmé*, remarking, however, "peut-être de nouvelles recherches sont-elles nécessaires pour s'assurer que ces observateurs n'ont pas regardé comme un appareil sanguin le système décrit par M. EDWARDS, et qui est en communication avec la cavité générale des Polypes." It appears to me to be only a just construction of the meaning of M. QUATREFAGES, as expressed by himself in the preceding passages, to state that he nowhere gives any clear proofs of having recognised in the fluid of "la cavité générale du corps" a *system* of circulation, definite and distinct in its laws, which, in the lower Invertebrata, replaces and represents that of the blood-proper as it exists in the vertebrated animal. The justice of this criticism is rendered undeniable by the tenour of the following observations:—"Chez les Invertébrés dont la cavité générale communique avec l'intérieur, la manière dont l'air est mis en rapport avec les principes qu'il doit modifier est évidente, et résulte du fait même de l'introduction d'une eau aérée...... La respiration du liquide de la cavité générale est plus difficile à reconnaître chez les Invertébrés dont la cavité générale est entièrement close." In the first remark he supposes that the fluid of the visceral cavity is the *aërating medium*, not itself the *subject* of the respiratory change. By the second observation he admits that the part performed by the chylaqueous system of fluid, in the Echinoderms and Annelids, in the mechanism of respiration, *is difficult to understand*. In this critical analysis of the valuable memoir of M. QUATREFAGES 'On the General Cavity of the Body in the Invertebrata,' I have, I think, clearly shown that there is scarcely anything in common either between the facts or arguments therein given, and the carefully recorded dissections and observations upon which I have sought in this communication to rest the superstructure of an important physiological law.

* Annals and Magazine of Natural History, by Mr. CARTER, August 1849.

† See Observations on the Cilia of Sponges in GOODSIR's Annals of Anatomy and Physiology, May 1852.

every species, the seat and scene of the processes of digestion, sanguification and respiration; it is, in addition, the direct agent of nutrition. It is chyme, chyle and blood in itself. In the zoophyte it is the only fluid element of the organism. In the tentacles of *Tubularia indivisa*, the fluid of the visceral cavity can be distinctly seen in motion in the axial channel. The fluid is charged, in this species, with minute albuminous granules, irregularly grouped, and formless or unorganized, appearing to consist simply of solid spherules, resulting from the solidification of albumen, Plate XXXII. fig. 1.

The bulk of this fluid consists of salt water; for when the specimen dries and the fluid evaporates, cubic crystals of chloride of sodium are seen amidst the albuminous molecules. This fluid was first seen in motion by Lister, then by Milne-Edwards, and by Van Beneden. It may be well here to observe, that the molluscan polypes of the *Flustræ*, *Escharæ* and *Bowerbankia*, are ciliobrachiate, and that the digestive organs are divided from the visceral cavity. In these genera, therefore, the fluid contents of this cavity receive no *direct* admixture of salt water through the tentacles, for the extremities of these organs are not perforate. It is replenished only through the stomach; the water is submitted to the agency of this organ before it enters into the visceral chamber. This fact explains the circumstance, that in these molluscoid polypes the fluid of the visceral cavity, as compared with that of the former group, presents a higher organic composition; its cells are corpusculated and evidently organized; many bear globules of oleine, although comprising several individual forms of cell; they are *constant* in their microscopic characters in the same species. The fluid is aërated in the tentacles. It is true-blood in its composition and functions, fig. 2.*.

Medusæ.—In *all* Acalephæ the digestive cavity is prolonged into a system of canals into which the contents of the stomach pass by direct communication. The gastro-vascular channels are to the Acaleph what the visceral cavity or the hollow interior of the polypidom is to the Polype. In both cases the contained fluid consists of a chylaqueous compound. In both, the containing chambers and canals are lined by a vibratile epithelium†.

* I have recently succeeded in bringing under direct demonstration the movements of the fluid in the perigastric cavity of the little freshwater *Hydra*. The distal ends of the tentacles are imperforate. The fluid is charged with minute oleous molecules. This marvellous little being is no longer an organic paradox. Its fluids and solids are now intelligible; the essential elements of its organism are unravelled.

† I had repeatedly and beyond doubt established this fact (by numerous observations on several species of Pulmograde and Cirrhigrade Medusæ found in the Bay of Swansea and the Bristol Channel) long before the advantage occurred to me of perusing the valuable paper of Mr. Huxley in the Philosophical Transactions 'On the Anatomy and Affinities of the Family of the Medusæ,' Part II. 1849. With reference to the digestive cavity of the Cryptocarp and Phanerocarp families Mr. Huxley remarks, "Whatever its appearance, it will always be found to be composed of two membranes, an inner and an outer. These differ but little in structure; both are cellular, but the inner is in general softer, less transparent and more *richly ciliated*." In the same paper a similar observation occurs in relation to the Rhizostomidæ, but from his memoir I cannot discover that

The presence of cilia on the internal surface of these canals strikingly and fundamentally distinguishes the latter from true blood-vessels, and intimately allies them, homologically, with the spacious perigastric chambers of the Echinoderms and Annelids.

The fluid contained in the gastro-vascular canals of the Medusæ is a compound of salt water and chyle. In the Rhizostomidæ it presents a yellowish hue, in *Velella* it is bluish; it is *always* corpusculated. The floating cells exhibit great *irritability*, but they are not locomotive; the minute molecules are mutually repulsive. In this fluid living polygastric animalcules are constantly met with. The fact of their constant presence proves the direct admission of the external sea-water into these canals, but they are in time digested. The largest corpuscles are furnished with an involucrum, fig. 3. In *Rhizostoma* (a specimen of average size) they vary in measurement from $\frac{1}{1800}$dth to $\frac{1}{2000}$dth of an inch. They are never organized to such a standard as to contain a defined centric nucleus.

The formative power of the cell is expended in the production of secondary oleaginous cellules and 'molecular base,' which constitute the contained parts of all the larger parent-corpuscles. The smallest cells are filled only with a limpid oleine, of slight refractive power. Evaporated, in *Rhizostoma* this fluid yields abundant crystals of chloride of sodium. In no Acaleph whatever are the gastro-vascular canals tunnelled in the *centre* of the substance of the disc. They are always situated as superficially as possible on the inferior surface of the disc in the Pulmograde Medusæ; in the Ciliograde under the external cuticle of the globe in immediate relation with the cilia. In this anatomical arrangement the physiologist discerns a true intention, that of exposing the fluid contents to the aërating agency of the surrounding medium. In *Rhizostoma* the yellow colour has its seat in the fluid, not in the floating cells. It is a fact of singular interest, that the corpuscles of the chylaqueous fluid in this, as in ALL other classes in which it exists, *vary in size* with the variations in the size of the body of the individual specimen under examination. In this respect they are diametrically distinguished from the morphotic elements of the *true-blood* in vertebrated animals, the corpuscles of which bear no proportion in size to that of the body of the animal from which they are taken. This general observation will be afterwards confirmed by a variety of particular exemplifications. It has now been shown that in Zoophytes and Medusæ sea-water is admitted in large quantities, more or less directly, into the chylechannels, with the contents of which it more or less directly mixes and vitally assimilates. This fact may at present be mentioned as another fundamental particular, in which the chylaqueous fluid, in ALL animals, is distinguished from the blood-proper, for into this latter fluid the external element is *never* immediately admitted; it is previously subjected to the influence of one or more organic processes; it is thus

Mr. HUXLEY had recognised *the principle* that in *all* Acalephæ the interior lining of the stomach and gastro-vascular canals was more or less generally ciliated, that the movements of the fluid contents were in great part due to the agency of cilia.

impressed with the *first* impulses of zoo-chemistry before it is fitted to enter into combination with the vital fluid. The facility with which the most depressed forms of life appropriate and vitalize a complex *inorganic* liquid, may be signalized as a true badge of zoological inferiority. When ejected from the body, as it often is, at the will of the animal, the vital fluid is renewed, organically, and corpuscles grow in it with incredible rapidity. The entire contents of the system of the true-blood can in no single instance be withdrawn from its vessels (except in very small quantities) compatibly with the preservation of life. Hence another fundamental difference between the physiological history of the blood-system and that of the chylaqueous. How significantly that of the latter speaks as to the "simplicity" of the living organism in those orders of which it constitutes the exclusive means of nutrition!

Echinodermata.—Physiologists, from TIEDEMANN to MÜLLER, commonly describe in this family *three* distinct systems of fluids; that, 1st, of the general cavity of the body; that, 2ndly, of the feet and water-canals; and that, 3rdly, of the blood-proper. The doctrine which maintains the perfect independence of these three orders of fluids, is advocated by these two illustrious anatomists. *Facts* will now be adduced which render it probable that these three apparently independent systems constitute really only a single indivisible fluid-system. They will be found to warrant no other conclusion than that in Echinoderms the system of the blood-proper is so rudimentarily formed, that its contents, by some means and in some undetermined manner, communicate and mingle with those of the general cavity of the body, since in every histological character the morphous elements and chemical compositions of the two fluids prove, under every mode of inquiry, to be identical. From the same method of examination, the inference is confidently drawn that the contents of the vascular system of the feet ("Das Wassergefässsystem" of MÜLLER and TIEDEMANN) are identical, chemically and histologically, with those of the visceral cavity. But, though rudimentary, the blood-proper system in the Echinoderms *does* exist. As regards its *central* channels, it is easy, by injection and inflation, to verify the descriptive statements of TIEDEMANN and MÜLLER.

It is important to the purport of this memoir, to ascertain the sentiments of MÜLLER with reference to the character and distribution of the blood-vessels in the Holothuridæ, to which more especially he has dedicated his recent studies, since, as these genera stand high in the Echinodermal scale, what is true of them must *à fortiori* be true of the lowest families of the class.—"Jedenfalls müssen die Blutgefässe zu den Körperwänden aus dem Innern des Thiers denselben Weg nehmen, wie die Nerven und die Wassercanäle, nämlich durch den Gabelfortsatz am obern Rande von je fünf Stücken des Kalkringes der Holothurien oder durch die fünf Stücken mit Löchern bei den Synapten. Dies sind, wie es scheint, die einzigen Durchgänge vom Innern zu den Körperwänden. An den Gekrösen der Holothurien, konnte ich keine Verbindungen der Körperwände und Eingeweide durch Blutgefässe wahrnehmen."

Speaking of the difficulty experienced by M. QUATREFAGES in detecting the vessels of the intestine in *Synapta Duvernœa*, MÜLLER incidentally remarks, "*Denn man darf die Wassergefässe nicht mit den Blutgefässen identificiren*, welche die vom Darm kommende Nahrungsflüssigkeit enthalten." In another place he speaks of "Die Unabhängigheit des Wassergefässsystems und des Blutgefässsystems von einander*."

From a careful study of the memoirs of MÜLLER, it has appeared to me to be certain that he has never succeeded in tracing the blood-system *to its periphery* even in the Synaptæ. He has only been able to show that a branch or two in some species is given off from the trunks at the roots of the tentacles, to be distributed over the integument. He nowhere offers a single remark as to the colour or composition of the blood. In commenting on the observations of QUATREFAGES, he seems disposed to deny the existence of cilia on the internal lining membrane of the channels of the true-blood.

It should then be remembered that MÜLLER, like TIEDEMANN, has succeeded in demonstrating *only the central* trunks of the blood-vascular system. In animals so large, with vessels so considerable in diameter, the question may be emphatically put, Why to an expert dissector should this difficulty of tracing the circumferences of the system exist? In every other class of animals in which a blood-system exists *at all*, nothing is so easy as to observe its peripheric segments. In the most delicate Annelid the capillary extremes of this system are readily detected. I reply, that in *the Echinoderms the blood-system has not yet evolved a circumferential plexus*. This is one of the characters of imperfection which marks *the first appearance* of this system in the animal series. It is because MÜLLER, as the first anatomist of the age, has reached by a distinct channel of inquiry, impliedly, the very same results with those which are presented in this paper, that I have digressed in the preceding remarks from a consideration of the contents of the blood-system to that of the system itself.

I have instituted laborious dissections on many hundred specimens into the blood-vascular and water-vascular system of the Asteriadæ, Echinidæ and Sipunculidæ. No Holothuridan species, in a fresh state, has yet fallen under my observation. I regret this circumstance the more, for in these genera the blood-system attains a higher degree of development than in any other of the Echinoderms.

The result of my own researches may be first conveniently stated under the form of the following propositions:—

1st. The blood-vascular system in the Echinoderms is *not* an independent and *closed* system of conduits; it is rudimentary and imperfect in its peripheral portions.

2ndly. The *internal* lining membrane of its channels is ciliated, a character which separates the blood-system of this class from that of every other in which it is known to exist, while it significantly attests its rudimentary condition.

3rdly. The fluid contents of the blood-vascular system are chemically and mor-

* Berichtigung und Nachtrag zu den Anatomischen Studien über die Echinodermen. 1850.

photically identical with those of the water-vascular system and with those again of the visceral cavity.

The *unity* of the two last systems of fluids has been recently advocated by MILNE-EDWARDS.—" M. MILNE-EDWARDS s'est assuré qu'une communication semblable existe entre la cavité générale du corps et les cœcums exsertiles des Echinodermes. Ces cœcums, bien distincts des pieds à ventouses, sont distendus non pas par le sang, mais par le liquide de la cavité générale. Quelques observations personnelles me portent à penser qu'il en est de même des pieds à ventouses eux-mêmes*."

M. QUATREFAGES, by whom this opinion of MILNE-EDWARDS is expressed, does not state the grounds upon which this latter physiologist rests his conclusions. I have been independently induced to ground the same belief upon the following demonstrations:—

1st. Injection thrown into the water-vascular system in the Asteriadæ will *first fill* the sand-canal, and then, by continuation of the injecting force, escape into the peritoneal cavity.

It is by this route, I infer thence, that a direct communication takes place between the fluid contained in the visceral cavity and that of the water-vascular system.

This office implies an adequate function to the sand-canal. It is a simple filterer of the fluid passing from the visceral chamber into the water-vascular system, and conversely. Muscular compression exerted upon the fluid in the water-vascular system (the walls of which are remarkably muscular) will force it *back* into the visceral cavity; a 'diastole' of the vesicles of the feet occurring coincidently with the compression of integumentary parietes of the general cavity, will cause a return of it again into the blood-vascular system. This is a beautiful and perfect mechanism.

The grounds whereon the identity of the fluid contained (in the Echinoderms) in the system of the blood-proper with that which fills the water-vascular system and the abdominal cavity is maintained, may be briefly stated as follows:—In *Uraster papposa* the oral membranous disc exceeds very much in diameter that of the common Asterias. This circumstance renders the circular central blood-vessel in the former much more conspicuous and accessible than in the latter. It was this fact which led me to make choice of *Uraster* as the subject of my researches. In this species the circular channel forming the centre of the blood-system coincides with the circumference of the oral membranous disc. The vascular channel (scarcely to be called a vessel) rests upon the hard edge of the calcareous framework. It is so closely and intimately adherent to the hard unyielding surface beneath, that 'the conditions' seem to be destroyed which might permit the contractions of this vessel as a circulating centre. No instance is known in which a *contractile* heart is thus anatomically connected: nor are the coats of this circular vessel, in *Uraster papposa*, endowed with muscular fibres. It is lined *internally* as well as externally by vibratile epithelium.

* Quoted by M. QUATREFAGES in his Mémoire, 'Sur la cavité générale du corps des Invertébrés,' Annal. des Sc. Nat. 1850.

No feat in anatomy is more practicable than in any species of *Sipunculus*, to bring under direct view in the field of the microscope, the blood-vessel which reposes on the œsophagus. Although more perfectly formed as a vessel, more defined in its parietes, than the circular vessel of the Asteriadæ, it may be placed beyond doubt that *its* interior also is lined by vibratile epithelium; that *its* contents are chemically and morphologically identical with those of the visceral cavity of the same animal. It may be mentioned here as a remarkable fact, that in the Sipunculidæ (at least such is the result of my examinations repeated with the utmost care upon many scores of living specimens) the vessel which rests upon one side of the œsophagus is *not* accompanied by a venous correlate on the opposite aspect of the cylinder, nor by one parallel to itself on the same side. It is a single channel, which *cannot be traced to a distal system of capillaries.*

In the Sipunculidæ there are no "Polian vesicles" attached to or developed from this vessel. The appearance of "vesicles" arises from the bulged knots into which the vessel irregularly contracts under the stimulus of the air at the moment of laying open the general cavity. To these facts, as illustrative of the singular conditions under which "the circulation of the blood" is first evolved in the ascensive progression of animal structures, the highest physiological interest attaches.

After this short historical introduction, the several characters of these three systems of fluids may be more carefully examined.

Blood-proper in the Echinoderms.—In the Asteriadæ and Echinidæ this fluid is *colourless*, and charged only with irregularly organized corpuscles; when placed under the microscope, it is quite impossible to distinguish these latter from those found in the peritoneal fluid, or in the water-vascular system of the same individual. In *Uraster papposa*, as already stated, the circular vessel and the radial trunks are so large and accessible as to be readily injected. Two methods may be adopted to determine the presence of cilia on the internal lining membrane of these vessels. In a fresh specimen a portion of the trunk may be cut out and laid under the microscope with a view to see *through* its parietes, a current of moving corpuscles driven along by vibratile cilia, or the vessel may be cut transversely into thin circular sections. These sections will exhibit cilia in active motion on *both* the outer and inner edges of the parietes of the vessel. In the Asteriadæ the *whole interior* of every organ (except the ovaries) in the body is coated with vibratile epithelium*. The blood of the Echinidæ is also colourless.

* In his recent essays, MÜLLER gives no further account of the blood-vascular system in *Asterias* than that which occurs in the following scanty passage:—"Das Wassergefässsystem zur Erection der Füsschen und das Blutgefässsystem der Asterien sind von TIEDEMANN so vollständig und naturgetreu beschrieben, dass ich nichts dazu nachzutragen gefunden habe, als dass der unter der Haut des Mundes auf dem häutigen Discus liegende Blutgefässring, ausser den von TIEDEMANN angezeigten und abgebildeten Aesten auch zu jedem Strahl einen Zweig giebt, der wieder 2 kurze Seitenäste abschickt, wie TIEDEMANN's Nerven der Arme. *Die Injection vom Blutgefässring gelang nur bis zum Anfang dieser Gefässe.*" In another passage he incidentally observes, "Zunächst unter der Haut am Munddiscus liegt nach TIEDEMANN das, was er den orangefarbenen Gefässring

Extreme care and caution are required to observe separately the true-blood. It can only be found in the circular vessel, embracing the œsophagus, immediately under the lantern. The real vessel is quite distinct from the circular band of bright red pigment, which in this species acute observers have mistaken for a veritable blood-vessel. It is very difficult to detect the presence of vessels along the edges or in the parietal substance of the intestine in the *Echinus*. The bright red pigmented cellules distributed through the tissues, sometimes seen in lines and reticulations, have nothing to do with the *blood*-system. The fluid contained in the circular vessel around the œsophagus is colourless. Its cell elements are precisely the same as those of the fluid of the general cavity. It is more opake than that of the visceral chamber, from the presence of a greater number of minute molecules*.

In the *Echinus* it has proved to me impracticable to isolate the vessel so accurately from surrounding structures as to be enabled to detect the presence of cilia on the internal lining membrane. The whole structural character of the vessel however leads me to this inference. Its parietes are not definitively organized like those of every other true vascular channel; cell and areolar fibres constitute the elements of its parietal structure. The preceding considerations have brought me to the belief, that in the Echinidæ, as in the Asteriadæ, the blood-proper has acquired scarcely any distinctive and independent characters; that the system of conduits in which it moves is so rudimentarily organized as to receive its contents, in some manner yet undetermined, *directly* (not by an act of elective, secretive absorption, as in the Annelida) from the fluid occupying the visceral cavity; that the blood-vascular apparatus, developed only in its central segments, is designed only to concentrate the nutritive force of the chylaqueous fluid upon certain of the more important viscera; and that the nutrition of the *peripheral* structures of the organism, such as the muscular, calcareous and integumentary, is sustained under the agency, exclusively, of the chylaqueous fluid.

In the Sipunculidan genera the blood-system is more conspicuous anatomically, although little more advanced physiologically, than that of the former families.

nennt, von welchem zur Tentakelrinne ein Ast abgeht. Dicht darunter soll sich das ringförmige Blutgefäss befinden, welches jedenfalls leicht aufzufinden, zu injiciren oder aufzublasen ist." It is no severity of criticism to lament that this description by the great modern anatomist is little in advance of the original statements of TIEDEMANN.—*Op. cit.* MÜLLER, Archiv, 1850.

* "Die Blutgefässe (der Echiniden) verhalten sich so wie es TIEDEMANN beschrieben. Um den Mastdarm her liegt der bekannte circulus analis dicht auf dem Skelet, auf dem er bei Echinus sinuöse Eindrücke zurück lässt, ohne Zusammenhang mit den Ambulacralcanälen. Er hat sehr zarte Wände und das Ansehen eines venösen Sinus. Er entspricht dem Gefässcirkel am Rücken der Asterien und steht in demselben Verhältniss zum Herzen wie dort. Wo der Gefässcirkel an das Becken der Madreporenplatte anstösst, erhebt sich aus dem Gefässcirkel die Fortsetzung zum Herzen, *welche sich vom Cirkelgefäss* aufblasen lässt. Um eine klare Vorstellung vom Herzen zu bekommen, muss man es bei Cidaris untersuchen, es ist bei Cidaris ein weiter, ganz gerader Canal mit dicken weichen Wänden. Nach oben setzt es sich in eine Arterie fort, welche in den arteriösen Gefässkreiss des Œsophagus übergeht."—Anatomische Studien über die Echinodermen, von J. MÜLLER, Archiv, 1850.

Like that of the *Echinus* it is confined to the alimentary canal. My dissections have never demonstrated more than *one* vessel extending back from the œsophageal ring, over the superior surface of the tube. If it be an artery there is no correlate vein. It is traceable along *one* border only of the canal, coinciding with the spiral convolutions of the latter as far as the anal outlet; no capillary system is traceable at its end ; no trace of *vessels* of any description can be discovered in the parietes of the alimentary canal. According to my observations, again and again repeated, the *interior* of the blood-vessel of the Sipunculidæ generally is lined with vibratile epithelium ; of the truth of this fact, extraordinary though it be, I am persuaded. The corpuscles of the fluid contents of this vessel were found in every species to be the *exact counterpart* of those of the fluid of the visceral cavity. *They are identical in colour, in diameter, in figure, and in structure*, figs. 4, 5, 6 and 7*. But in the fluid of the blood-vessel they are more numerous relatively to the bulk of the fluid than they are in that of the visceral cavity. If the true-blood penetrated into the substance of the solids by means of capillary vessels, there would in the Sipuncle exist no difficulty in tracking its course by means of the corpuscles. It is certain that in these Echinoderms it is not distributed throughout the solid parietes of the alimentary canal. The movement of the corpuscles, which is oscillatory, cannot be traced in *any* case beyond the limits of the primary trunk. In the Vermigrade Echinoderms, then, as in the Echinidæ and Asteriadæ, the system of the blood-proper is a partial and local development. It has few, if any, systematic relations. It fulfils but a very insignificant part in the nutrition of the organism. In the particular of the red colour of the blood-proper the Sipunculidæ approximate the Annelida. In the character however of the presence of corpuscles—organized cells—in the blood (on the supposition that it forms an independent system and not a part of the chylaqueous), they transcend the latter class and approach the higher Articulata.

The corpuscles of the fluids in the vessel and in the visceral cavity present a pink tinge. Each corpuscle is flat and irregularly oblong; remarkable uniformity prevails in their size and structure, figs. 4 and 5. Each exhibits a bright, small, highly refractive nucleus; in some cells a second may be seen. The dimensions of this nucleus are disproportionately small in relation to the containing cell. The colour is dissolved in the fluid between the nucleus and involucrum. These corpuscles are

* Although my observations are quite at variance with those of Dr. PETERS as regards the number and distribution of the blood-vessels, our researches on the corpuscles of the fluids are mutually confirmatory. "Betrachtet man dieses Gefäss mit einer starken Loupe, so sieht man einen Strom von Körperchen, welcher sich nach dem Schlund hin langsam fortbewegt, während man bei dieser Vergrösserung in den beiden danebenliegenden rothen Gefässen noch gar keine Körperchen oder Bewegung wahrnehmen kann. Bringt man dagegen den mit Wasser gefüllten Darm eines frischen Thieres unter das zusammengesetze Mikroskop, bei einer etwa 50-maligen Vergrösserung, so sieht man in dem mittleren gelblichen Gefäss die schönste Wimperbewegung, wodurch die Kugeln, welche sich jetzt deutlich als Eier erkennen lassen, vorwärts getrieben werden, in den beiden rothen Seitengefässen dagegen, Blutkörperchen von derselben Form wie in dem Körpergefäss, welche sich ohne Wimperbewegung, und unregelmässig nach vorn hin bewegen. Sehr oft liess sich nichts weiter unterscheiden, als dieser einfache eierführende Canal mit den beiden Gefässen zur Seite." Ueber die Fortpflanzungsorgane des Sipunculus. Von Dr. WILLIAM PETERS, MÜLLER's Archiv, 1850.

peculiar to, and strikingly characteristic of, the nutritive fluids of the Sipunculidæ. In different species they exhibit slight variations of form and size. They are the proper and invariable morphous elements of the fluids in these genera. In many instances however there exist *with* them in the chylaqueous fluid, sperm-cells and ova in variable proportions.

These corpuscles, when observed in the chylaqueous fluid, are not mutually repulsive, but when examined while yet in the blood-channel, they manifest the most extraordinary restlessness. The motion of the individual particles is singularly irregular, as though due to attractive and repulsive forces acting among themselves. The compression of the object under the microscope increases the confusedness of the motion. But what is the real explanation of a phenomenon so unusual in the history of blood-vessels? Are the corpuscles self-motive, or is their agitation excited by an external cause? The former question is at once set at rest by the observation that when the corpuscles escape *out* of the vessel, their motion instantly ceases. The cause is not therefore *in* themselves. The real exciting force is derived from the vibratile epithelium by which the *interior* of the vessel is lined. But is not this extraordinary fact opposed at once by every dictate of analogy? It is, though not by that of the analogy of the blood-system in other genera of Echinoderms. Never before has the physiologist recognised the anatomical *incipiency* of the blood-vascular system of this class. It is the first grade of a novel apparatus in the living organism. Viewed in this relation of imperfect development, the presence of cilia on the interior of its conduits occasions no surprise. From the utter insignificance in magnitude and distribution of the blood-proper system in the economy of the Echinoderms as compared with the chylaqueous, it is beyond dispute that it is upon the latter that devolve the vital offices of nourishing the solids. I have lately discovered that the integuments of all the nude Sipuncles is remarkably fenestrated, *not* with open perforations, but with elliptical spots closed only by a thin ciliated epidermis; nothing therefore but a delicate cuticle intervenes between the chylaqueous fluid contained in the visceral cavity and the aërating medium without. No mechanism can be better adapted to favour the interchange of gases between the fluids divided by such a partition. In the Sipunculidæ the tentacles are *hollow* appendages, ciliated within and without, and penetrated freely by the chylaqueous fluid. It seems hopelessly impracticable to demonstrate any traces whatever of blood-vessels proper in the parietes of these tentacles. They appear therefore to be designed to expose, for the purposes of respiration, the chylaqueous fluid rather than the true-blood. It is however probable that in the Holothuridan genera, as in the majority of Annelids, the true-blood has *its* respiratory apparatus, while the chylaqueous fluid, in the same individual, has distinctly another. With reference, then, to the *blood-proper* of the Echinoderms, it may be stated that, in the genera *Asteriadæ* and *Echinidæ*, including the *Ophiuridæ* and *Ophiocomidæ*, the morphotic elements are *almost unformed*, the fluid is almost a non-corpusculated albuminous solution. In the Sipunculidan and Holothuridan

genera, however, the presence of *determinately* organized cells floating in the nutritive fluids indicates an advance in the organic composition of the latter, as compared with those of the inferior Echinoderms. Thus the morphous elements of a living fluid become criteria of its zoological *status*.

Chylaqueous Fluid of the Echinoderms.—In the economy of all Starfishes the chylaqueous fluid is far more voluminous, and enacts a much more important part than the blood-proper. The latter system, in the *Crinoidea, Asteriadæ,* and *Echinidæ,* bears to the former an insignificant proportion. In the Sipunculidæ it has assumed a somewhat greater relative development. In the Holothuridan genera it exhibits the most advanced condition under which it is known to exist in the Echinodermal series. The proportion between these two systems, when they exist together in the same individual, is thus shown to be inverse. The fluid contained in the "water-vascular" system and peritoneal cavity of the Echinoderms is described both by TIEDEMANN and SHARPEY* as consisting of pure unorganized sea-water. In his Monograph on this class, MÜLLER avowedly adopts the same view. Analogy and demonstration will now be shown to be opposed to this opinion.

The peritoneal cavity exists in ALL Echinoderms. In ALL species this space is occupied by a fluid; in ALL SPECIES, including the Ophiocomidæ and Ophiuridæ, this fluid penetrates through hollow axes, into the arms and lobes, and ALL the membranous processes of the tegumentary system. In ALL Echinoderms the INTERIOR of the stomach *and its dependent cœca* are lined with vibratile epithelium. This fact establishes a connection between the Echinoderm and the Medusæ, the gastro-vascular canals of which were proved to be similarly ciliated, whilst it disjoins them in a striking manner from the Entozoa and Annelida, digestive organs of which, as will be afterwards proved, are *never* furnished with vibratile epithelium. The boundaries of the peritoneal cavity are universally ciliated. *All* the integumentary *membranous* processes are lined *within* and *without* with ciliary epithelium, and consist of hollow prolongations of the peritoneal cavity. In *Asterias rubens,* the cutaneous membranous processes are readily distended by injection thrown into the peritoneal cavity. Thus injected they rise, in relief, to a considerable distance above the plane of the integumentary surface.

They are *cœcal* at their distal ends. This fact is absolute throughout the Echinodermal families.

These processes in *Asterias* are disposed, on the dorsum of each lobe, in four longitudinal series. They constitute the veritable respiratory organs. They are designed to expose to the external, aërating element, not the true-blood, but the chylaqueous fluid, the contents of the peritoneal cavity. If this fluid consisted only of pure sea-water, what chemical change could result from such an exposure? No endosmotic and exosmotic currents could occur between fluids of identical densities. And wherefore that remarkable movement of the corpuscles of the chylaqueous fluids in the

* Art. "Echinodermata," Cyclop. Anat. and Phys.

interior of these processes, if not for the purposes of aëration? In the solid parietes of these membranous processes no vestige of a blood-system can be discovered.

The *fluid* of the peritoneal cavity in *all* the inferior Echinoderms is charged with globules or cells, which, however, are less determinately organized, and fewer in number, than those of the chylaqueous fluid of the superior genera. That of the Asteriadæ and Echinida is less corpusculated than that of the Ophiocomidæ and Ophiuridæ, the arms of which are unoccupied by the prolongations of any of the viscera; that, on the other hand, which is found in the peritoneal space of the Holothuriadæ, is probably charged with highly organized cells, and that too in presence of a complex blood-system, and of a peculiar organ expressly designed for the introduction of water into the interior of the body. If the contents of the peritoneal cavity consist of pure sea-water, whence the necessity for the superaddition of this peculiar and unparalleled organ, 'the respiratory tree'? It is not the homologon of the peritoneal space of the Asteriadæ, as maintained by physiologists, for this space as well as this organ exists in *Holothuria.* It will be afterwards proved, unquestionably, that if the office of this 'tree' be respiratory *at all*, it can discharge this function only in a secondary and incidental manner.

In the peritoneal space of the *Sipunculidæ* there exists a large volume of opalescent fluid, holding in suspension corpuscles of definitive organization; and *yet* the *bulk* and basis of *this fluid* also is *salt water* (figs. 6 and 7). They exhibit a pink hue, like those of the blood-proper, figs. 4 and 5 of the Sipuncles.

They are flattened, irregularly oval cells, bearing a single minute nucleus. These cells, in fact, correspond in every minute particular of colour, structure, figure and dimensions, to those found in the blood-vessels of the same Sipuncle. Wherefore this identity? The question cannot be eluded. They *must* be one and the same. Evaporated, chloride of sodium is disclosed in a rich crop of cubes and octahedrons.

The morphotic elements of the fluid of the peritoneal cavity of *Asterias rubens*, which in number and amount vary at different seasons, consist of irregular cells (fig. 8), jagged and broken in many instances, nucleated and perfectly organized in others; some cells are compounded of several minutely granulated secondary cells, the group being enveloped in an involucrum, from the circumference of which thready appendages project. These latter cells are NOT sperm-cells; the thready processes are accidental formations, depending upon the fibrillation of the contents of the cells; in some examples the threads occur under the character of a flattened projection or bulging of the involucrum. A "molecular basis" may also be observed in form of minute cells and granules. If the specimen of *Asterias*, from which the fluid is taken, be allowed to remain some time out of the water before the examination is made, these corpuscles may be obtained in far greater number. The corpuscles in the *water-vascular* system *or feet*, are always found *to be identical with those of the peritoneal fluid.* The *contents* of the digestive cæca are *identical in composition* with the peritoneal fluid; it differs only in the absence of the largest cells of

the latter. Its 'molecular base' is like that of the latter, it affords abundant crystals of chloride of sodium like the latter. These and other reasons have satisfied me that the bulk of the fluid contained in the peritoneal cavity of *Asterias* is derived from that which enters through the mouth into the digestive cæca, in which the first phase of the digestive process is performed; the second and subsequent changes, by which it is raised to a higher grade of organic composition, occur during its sojourn *in the peritoneal space*, into which it passes by exosmosis, from the digestive cæca. If the individual be placed for some time in pure sea-water, destitute entirely of organic material, the digestive cæca and the peritoneal space will be found to contain the same fluid, almost completely free from all traces of organic substances*.

* I have instituted, at great labour to myself, a series of variously devised observations, with a view to set at rest, if possible, the question relative to the real source and nature of the fluid contained in the peritoneal cavity of *Asterias Rubens*, and through this example, to close the controversy, in relation to all other Echinoderms. First, then, is it salt-water? if so, how does it gain admission into the cavity in which it is contained? For answer, I affirm that under the ordinary circumstances under which these animals are examined, *it is almost* pure sea-water; but in the *natural* state (that is, when the water taken into the digestive organs contains, as it always does in their native habitat, organic substances, living and dead), *it is a chylaqueous fluid*, in which the first steps of vitalization and organization have commenced, and that in *Asterias* IT IS THE REAL SUBJECT of the respiratory process, the true-blood not being brought in any way under the agency of the external element. This answer applies to ALL Echinoderms. The existence and offices of this fluid explain the fact of the suppressed or rudimentary development, under which the true-blood system obtains in these animals. The latter performs merely the functions of pabulating very partially the solid elements of structure: the chylaqueous fluid is the veritable seat of the blood-making and respiratory processes. And 2nd, I reply that every method of examination fails in proving the existence of any pores or orifices of any sort whatever in the integumentary boundaries of the peritoneal space in *Asterias*. MÜLLER has arrived at the same conclusion.

He remarks, "Die respiratorischen Röhrchen auf dem Rücken der Asterien, welche mit der Bauchhöhle communiciren, sollen zufolge der Injectionen von TIEDEMANN am Ende offen sein, und zum Wechsel des Wassers der Leibeshöhle dienen. Nach EHRENBERG dagegen sind die Röhrchen am Ende geschlossen, er sowohl als SHARPEY sahen die Strömungen im Innern am Ende umkehren. An jungen lebenden Exemplaren des *Asteracanthion violaceus* sah ich dasselbe, und es gelang mir nicht eine Oeffnung wahrzunehmen." (MÜLLER, Archiv, 1850, 121.)

On the contrary, in the larvæ of the Echinoderms, AGASSIZ maintains, on the ground of his own observations, that the external water passes by a direct stream into the cavity of the body. Such an improbable statement requires however to be carefully verified. These are the words of AGASSIZ:—"Bei den niederen Thieren besteht eine innigere Verbindung zwischen dem Innern und dem umgebenden Medium, als in einer der höheren Classen. Das Wasser strömt durch unzählige Poren in ihren Körper und füllt seine Höhle. Einige von diesen Röhren nehmen eine sehr eigenthümliche Anordnung in den Echinodermen an und dienen zugleich zur Ortsbewegung. Da dieser Apparat einer der ersten ist, welche in dem Jungen ercheinen, so muss ich seine Structur bei den Seesternen anführen. Die hohlen Füsschen sind in der Durchschnitts-Abbildung herabhängend dargestellt. So haben wir einen hydraulischen Apparat von sehr zusammengesetzter Natur," &c.

Injections carefully thrown into the peritoneal space distend, and enter into the membranous projections of the integument already described, but it never escapes externally, except through a rupture of the delicate containing parts. A *coloured thin* fluid (*i. e.* sea-water) cautiously injected into the cæca through the mouth (first laying open the integuments), will distend these parts, and *invisibly* and *without rupture* slowly transude into the peritoneal space; but injection consisting of size diluted with water, will not escape out into the

The Asteriadæ in general coincide with *Asterias rubens* in the microscopic and chemical characters of the chylaqueous fluid. In *Solaster papposa* (fig. 9), the motion of this fluid in the hollow interior of the membranous appendages may be readily demonstrated in a living specimen. The morphotic elements of the fluid in this genus consist of nucleated cells, flattened in form, charged in general with little or no granular matter, inferior in dimensions to those of *Asterias*. The molecular base, as obtained by evaporation, is small in amount, while the fluid evidently holds albumen in solution; for when collected in sufficient quantity, and treated with nitric acid, it becomes distinctly opalescent. In fig. 9 these corpuscles are accurately represented as they were found in several specimens examined, and magnified 350 diameters. They vary so much among themselves, and according to the size of the specimen, that exact measurements of individual examples would yield no useful results. In *Cribella oculata* (fig. 10) the cells of the chylaqueous fluid are more globular in figure; the largest are distended with secondary cellules, and nucleated, the involucrum of the maternal cell being more distinct than ordinary in other genera. In this species also, the granular matter of the fluid is wanting; nitric acid, however, gives an obvious opacity.

In the *Echinidæ* the blood presents a slightly higher grade of development than that of the Asteriadæ, and the digestive canal is furnished with a second orifice. The canal is always found to be filled with solid ingesta, composed for the most part of sand and clay. These characters constitute important zoological features. They explain the fact of the diminished bulk and pure water-like appearance of the contents of the peritoneal cavity in *Echinus*. I have proved, as conclusively as a negative pro-

peritoneal space; there are therefore no OPEN perforations in the parietes of the digestive cæca. From the interior of the latter organs into the former space, no fluids therefore CAN pass but by exosmosis. When a fresh, living Asterias is immersed in fresh sea-water, coloured with cochineal or carmine, and allowed to remain thus immersed for about an hour, and then carefully washed in clear sea-water, and then opened, it will be found that the contents of the peritoneal cavity are perfectly free from the smallest trace of the coloured fluid, while it may be always, under the conditions of this experiment, detected *in the interior of the cæca*. These and parallel observations prove that *Asterias* continually, and for the purpose of feeding, draws into the stomach a large volume of water, sending by a determinately directed pressure, a portion into the cæca, and rejecting the remainder again by the mouth. Of *hundreds* of living, healthy Starfishes which I have dissected, it is remarkable to relate, that *not one* has ever contained anything whatever in the stomach. The primary process of digestion is performed in the Asteriadæ in the central stomach, and that rapidly, the unappropriated portions being immediately disgorged, while the rest is admitted into the digestive cæca. The cæca are never charged with anything but *sea-water*, rendered slightly opake by the chyme and the parietal secretions of these parts. This fluid therefore exhibits a grade of organization inferior to that contained in the peritoneal cavity, since the latter is replete with unquestionably organized elements, of which the former is destitute. The true food of the Starfish appears therefore to consist of nothing but sea-water, and those albuminized organic substances which it may perchance hold suspended or dissolved. According to my examination, the chylo-peritoneal fluid in all the asteroidal and globular Echinoderms is intimately analogous in composition. In the Vermigrade orders, it resembles much more that which exists in the Annelida; it is beyond question here a vital fluid. In the intestine of the Holothuriadæ and Sipunculidæ, sand and other refuse matter are always found.

position admits, that the peritoneal cavity in these Echinoderms, like that of the Asteriadæ, does not *openly* communicate with the exterior. The fluid contents enter at the mouth, perform a part in the first stage of digestion, and then carry a portion of the product thereof in solution, probably by exosmose, into the open cavity of the body, where the fluid is set in motion, determinately, by the agency of vibratile cilia, travels round and round the concave of the shell, penetrates the hollow axes of all the membranous processes of the shell, *where it experiences the change of oxygenation*, conveys the RESULTS of this change to *the blood-proper*, and replenishes the water system or ambulacral feet. It contains flattened corpuscles (fig. 11), the largest of which are provided with an involucrum, bearing particles of limpid oleine. A cell here and there may be seen, the involucrum of which apparently projects out like a cilium, and when these are numerous it is easy to mistake such an appearance for those characteristic of a sperm-cell. It is *really* due to the fibrinous contents coagulating in *lines* on escaping. When a small test-tube is filled with the peritoneal fluid (an experiment which demands the sacrifice of ten or twelve individuals), nitric acid will prove clearly the presence of albuminous principles. From the total absence of proper-blood-vessels in the membranous structure and processes of the shell, or integumentary system of *Spatangus* and *Echinus*, from the fact that these latter processes are hollow, and openly communicate with the chamber containing the chylaqueous fluid, by which they are filled, and that their parietes *within* and *without* are profusely lined with cilia, the conclusion is not to be disputed, that they constitute the real organs of breathing, and that the real *subject* of the respiratory change is the chylaqueous fluid, and not the true-blood, which is limited to the central viscera in its circulation. This conclusion, drawn by fair induction from anatomical and physiological considerations, is corroborative of the view suggested by the results of microscopic and chemical inquiries, that the fluid contents of the peritoneal cavity in the Echinidæ, however nearly in appearance they may resemble sea-water, are vitally and organically endowed. In the Ophiuridæ and Ophiocomidæ (fig. 12) the chylaqueous fluid, which occupies the cavities of the body and the hollow axes of the arms, is essentially similar in composition to that of the former Echinoderms. In these genera also it is unquestionably the fluid which is really oxygenized in respiration. An exact and faithful account has now been given of the chylaqueous fluid of the inferior families of Echinoderms. This distinction must be noted between it and that of the superior genera; that in the Asteriadæ, Echinidæ, Ophiocomidæ, and Ophiuridæ, the morphotic elements have not, taken as a whole, attained to the character of *definitively* organized cells. They do not in these genera conform so obviously to one typical size and figure, as to show that they are produced and multiplied under the directive influence of a *determinate* force. They are unclassifiably various in form and shape. They are too scanty in number to act an important part in vitalizing the fluid in which they are suspended; though it must again be repeated, this fluid is unquestionably an albuminous, living, corpusculated solution. These

observations suggest the inference, that the blood-making process in the examples of these Echinoderms is to some extent independent of floating cell-agency. The absence of proper-cells from vital fluids, attest to the physiologist a near approach, as respects the composition of such fluids, to the standard of an inorganic body. And the novel truth will flow from these researches, that, in structure and mechanism of nutrition, the living solids of the organism descend from the complex to the simple in the *same degree* as that in which the fluids may have fallen in the scale of vitality. During the examination of the fluids of other classes, the singular fact will be established that the chylaqueous fluid of the young of the Annelid, and of the larvæ of some Insects, *is scarcely, if at all, corpusculated*; that the fluids become more and more charged with floating-cells the older the animal becomes, and that these cells actually change their structural characters as the growth of the animal advances. What is transitory in the Annelid and the Insect, may be the permanent condition in the Echinoderms. Then, the paramount question arises, in the absence of floating-cells from the fluids of the Echinoderms, in what manner are those fluids vitalized, raised from the inorganic to the organic condition? It is probable that as *all* the fluid which reaches the visceral cavity passes through the digestive organs, and transudes the solid parietes of the latter, by which it receives the impress of the vital force from the living solids, its organic matter assumes the form of albumen and fibrine, which, incorporating with salt-water, becomes a vital fluid.

The anatomy of the Holothuriadæ and Sipunculidæ places beyond controversy the correctness of the conclusions presented in the preceding pages, in relation to the real physiological meaning of the chylaqueous fluid in the inferior Echinoderms. In these orders the integumentary hollow membranous process more or less completely disappears, and is replaced by the peculiarly fenestrated structure of the integuments formerly described in the Sipunculidæ, to which is superadded a system of plumose tentacula or ramose cirrhi, which are confined to the cephalic extremity of the body. The real structure of these beautiful appendages has never yet been demonstrated. All naturalists have *guessed* that they fulfil a respiratory office. No observer has attempted to unravel the mechanism by which this office is accomplished*.

In different genera of these two orders, these appendages vary illimitably in number and size and figure. Such external diversities are however accompanied by no structural and essential differences. In ALL species they constitute merely hollow

* For confirmation of this statement I refer to all the recent works of French and English Comparative Anatomists, especially to CROCHARD's edition of the 'Règne Animal.' It is impossible that the true structure of the cephalic appendages of the Sipunculidæ and Holothuriadæ could have been determined without a previous knowledge of the real physiological signification of the chylaqueous fluid in the animal series. The organs destined to receive THIS fluid are strikingly different in structure from those designed to circulate true-blood. The cephalic appendages of these Vermigrade Echinoderms are not comparable in the remotest degree to the gills of fishes. Between them and the respiratory organs of some species of Annelida there is, however, a very intimate analogy.

processes, though variously scalloped, *into which the fluid of the visceral cavity freely penetrates.* At their bases they are supplied with a few true-blood-vessels. They are lined *within* and *without* by ciliary epithelium; in this particular they are not to be distinguished from the corresponding organs of those species of Annelida in which the chylaqueous fluid alone is submitted to aëration.

It is important to remember, that, notwithstanding the existence of "the respiratory tree" for the *direct* admission of water into the interior of the body, in *Holothuria* the peritoneal cavity, as formerly stated, is filled with a highly corpusculated fluid which penetrates the hollow cephalic tentacles, as in *Sipunculus*, to receive the influence of the surrounding medium. In the Sipunculidæ the peritoneal cavity is occupied by a richly organized fluid profusely charged with corpuscles of peculiar and distinctive microscopic characters (see figs. 6 and 7). The whole interior of the cavity is lined with vibratile epithelium, and the motion of cilia prevails over the hollow interior of the cephalic tentacles, sustaining in constant and rapid oscillation the corpuscles of the chylaqueous fluid, and in these situations ministering directly to the function of respiration. As exhibited in the above illustrations, which are strictly faithful to the original, the morphotic elements of the fluid of the peritoneal cavity in the Sipunculidæ differ remarkably from the corresponding elements in *all* other Echinoderms. They consist, as in part already described, of nearly flattened oblong bodies, inclining to the oval, containing a bright, highly refractive and very small nucleus. In some cells a second nucleus may be discerned. The parent cells are filled with a fluid which is perfectly devoid of granules and molecules. *This fluid* has an obviously pink or faint red tinge. From the contrast between their own colour and that of the fluid (opalescent) in which they float, the cells become beautifully conspicuous objects; but in the Sipunculidæ and Holothuriadæ these bodies are so numerous as to impart to the fluid, viewed as a whole, a thick, milky pink appearance. The *organic* quality of this fluid in these orders, at all events, it is impossible to doubt; nor can it be disputed for a moment, that the cavity in which it is contained in the Vermigrade Echinoderms corresponds, nay, is anatomically identical, with that which holds the LESS opake and less organized peritoneal fluids of the Asteriadæ, Echinidæ, Ophiuridæ and Ophiocomidæ. In these orders, severally, it is the same fluid, chemically and physiologically. In all it occupies the peri-visceral or peritoneal chamber. These indisputable facts establish conclusively the view which denominates the peritoneal fluid of *Asterias*, even though it may *look* like pure water, as a vitally endowed fluid. In addition to the bodies above described, which are the *proper* corpuscles of the chylaqueous fluid in *Sipunculus Harveii* and *S. Johnstoni*, *others* may be observed in every specimen and at every season of the year, which severally resemble germ-cells and sperm-cells*.

* I have designedly avoided in the text all discussion as to the real character of these ova- and spermatozoa-like bodies which are constantly found in the chylaqueous fluid of nearly all zoophytic, radiate and articulated animals. In another communication I propose to contribute materials which will probably set the question at

There exists no difficulty whatever, in the case of the Sipunculidæ, in proving beyond doubt, that in them, at all events, the sea-water (which in these orders, as in the inferior Echinoderms, constitutes the bulk and basis of the chylaqueous fluid) is NOT *derived directly from without.* I have repeatedly shown, by variously contrived injections, *that no fluid whatever* will escape externally through the skin or integument, and that the hollow membranous appendages at the head, and which the animal exserts *by distending* or injecting them with the fluid of the peritoneal cavity, proving their hollowness, are *cœcal at their distal extremities.* As far as it is possible to arrive at certainty in anatomical demonstrations by negative proofs, it may now be held as established, that in ALL Echinoderms, to which these proofs apply, *i. e.* the Asteriadæ, Echinidæ, Holothuriadæ and Sipunculidæ, there exist no perforations or orifices in the integuments in any part, or under any form, through which the external water can *directly* gain admission into the peritoneal cavity. The inference is then irresistible, that it enters at the mouth in form of alimentary material, reaches the digestive canal, and thence passes into the great cavity which surrounds the viscera. In the Echinodermata, as a class, it is impossible to dispute the importance of the functions enacted by the fluid contained in the peritoneal cavity (profusely ciliated as are its walls), when regarded especially in connection with the peculiar structure and situation (when distributed universally over the integumentary surface of the body, as in the Asteriadæ and Echinidæ, or in part centralized at the head, as in the Sipunculidæ and Holothuriadæ) of the organs of respiration.

I have already lamented that my opportunities of examining the Holothuridan Echinoderms, in the living state, have been few. Several points of surpassing interest, as the climax and triumph too of the preceding inquiries, in the anatomy of these genera demand scrupulous revision. 1st. Does the water admitted into the "respiratory tree" serve to aërate the blood-proper or the chylaqueous fluid? This question can only be answered by first determining the exact situation of the blood-vessels in relation to the parietes of this unprecedented organ. 2nd. Are the tentacles the scene of a *double* respiratory process, by which the blood-proper and the chylaqueous fluid are aërated simultaneously? Analogy renders it certain that the integuments of these genera, like the Sipunculidans, are 'fenestrated,' and that with express view to the aëration of the contents of the visceral cavity. These inquiries have thus placed in clear light the interesting fact, *that there prevails but one essential type or plan of structure in the integumentary system of all Echinoderms,* and that the blood-proper may have its own respiratory apparatus, or that it may be aërated through the medium of or by the chylaqueous fluid, *itself having first received* oxygen from the surrounding element.

The Entozoa constitute, really, the true commencement of the Annelida in the

rest. At present I will only commit myself to the statement, that in the fluid of the peritoneal cavity of the Sipunculidæ the *germ-cell*-like bodies are veritable ova, and the sperm-cells are veritable spermatozoa.

zoological series*. Excluding for the present the cystic orders, the two leading divisions, established by Professor OWEN under the appellations of Cœlel- and Sterelmintha, are distinguished from each other by a deep line of demarcation, two great classes of Entozoa which differ in organization far more remarkably than any helminthologist has ever yet supposed. On this occasion, however, it is proper that my observations should be confined to a consideration of the fluids.

In the *Nematoidea* the intestine is scarcely at all attached to the integumentary cylinder. The space which intervenes is filled with a corpusculated fluid, remarkable for its viscidity and the molecule-like size of its corpuscles, which is truly chylaqueous. The system of the blood-proper in all Entozoa is very inferiorly developed, and the blood-proper itself in *all* species is colourless and perfectly fluid, holding no globules or cells of any sort in suspension. In this particular they are identical with the Annelida. This fluid, contained in the peritoneal cavity, is the real reservoir of their nutrition. Traced through the class in living specimens, its history will prove the history of the real mechanism of nutrition in these animals. The Cestoid Entozoa differ from the Trematoid and Nematoid orders, in the same characters exactly, as the Nemertine Annelida differ from all the other orders of their class. In the *Cestoidea* the alimentary canal is intimately adherent to the integuments, obliterating the peritoneal space and constituting the solid-worms (Sterelmintha) of Professor OWEN. The true chylaqueous fluid is contained IN the canal in this order, a disposition of the fluids which will be found to prevail also in many species of Trematoid and Nematoid worms. Differing in anatomical situation, these two varieties of fluids will be found to differ in physical characters.

In those Entozoa in which the chylaqueous fluid is contained *in* the recesses of the alimentary organ or digestive canal, it presents characters which distinguish it conspicuously from that of those families in which it occupies the cavity (visceral) *without* the alimentary canal. In the latter case it oscillates freely in the cavity, driven by the muscular contractions of the intestinal and integumentary parietes. In the former it moves very little in its containing cavity. This is true of all Entozoa allied to *Tænia*. The fluid contents of the alimentary system, which in many species had neither an inlet nor an outlet, is quite stationary. *In these worms no part either of the exterior or interior of the body* is ciliated, although those Annelida, such as the

* This observation is founded upon, and justified by, the results of my researches into the organization of some of the Nematoid and Cestoid Entozoa[1], but especially into the anatomy of the Nemertine Annelida, under which division I include the *Gordiusidæ, Planariadæ, Borlasiadæ* and *Liniadæ* orders of Annelids, on the TRUE structure of which no light has hitherto been thrown by anatomists, and between which and the Cestoid Entozoa especially, affinities, in structural plan of a remarkable character, and hitherto unrecognised, exist. As my opportunities for examining *recent* Entozoa have been few, I regret that I cannot in the text present many examples of the exact microscopic characters in this class of the fluids.

[1] See the author's Report on the British Annelida, Transactions of the British Association, 1851.

Nemertina and Planariæ, whose organization, as already stated, is remarkably analogous to that of the Cestoid Entozoa, are universally covered externally by a ciliated epidermis.

The characters of the chylaqueous fluid in the entozoon of the Hake are illustrated in fig. 13. It is a thick tenacious fluid, bearing a vast multitude of minute, highly refractive molecules, distributed through a hyaline semifluid substance resembling the white of egg. I have proved, by repeated observations, that this fluid is the normal contents of the alimentary organ of these worms. It intimately resembles the semifluid substance which fills the blind diverticula of the digestive system of the Planariæ. It is in both instances undoubtedly a vital, nutritive fluid. It is in *this fluid* that is performed the part which devolves upon the corpuscular elements. When, accordingly, in some of these sterelminthous species *a space does* exist between the exterior of the digestive organ and the solid parietes of the body, that space is filled only with a limpid, non-corpuscular liquid, which is fitted to answer no other than the mechanical purpose of facilitating the slight movements of which the intestine is capable. It may be accepted as a rule applicable to all Entozoa and all Annelida, that when the intestine is *intimately* tied to the integuments, the *ordinary* chylaqueous fluid is materially reduced in volume, or altogether disappears. Under such circumstances, in the solid Entozoa it reappears under a new character, although virtually the same fluid, *in the interior* of the digestive system. In some species of Annelida, however, as the Earth-worm and the Leech, the diminution or suppression of the chylaqueous fluid is compensated by a correspondingly greater development of the true-blood system. Future researches will inevitably show that in the Entozoa the blood-proper system is a very subordinate element of the organism. For the maintenance of the living solids, so striking in these animals is the "simplicity" of their structure, the chylaqueous fluid will be found physiologically sufficient. An attentive study of the fluids will result in the discovery of an unfailing clue whereby in these animals to reconcile with physiological principles the paradox of the arrangement and histology of the solids. By no other road can this desirable point be attained*.

* I have recently studied with great attention the valuable contributions of M. SIEBOLD[1] and M. VAN BENEDEN[2] to helminthology. I am persuaded that these distinguished men have not yet discovered the path which is destined to conduct the physiologist to a true understanding of the organization of the Entozoa. I warrant this bold statement by *the facts* which already my own labours have enabled me to establish. The *fluids* will unerringly conduct the future student to a perfect comprehension of the *solids*. The *solid elements* of these paradoxical organisms will ever remain insoluble enigmas if studied independently of, and without refer-

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[1] Mémoire sur la Génération Alternante des Cestoïdes, suivi d'une Révision du genre Tetrarhynchus. Par C. T. de SIEBOLD. Traduit de l'Allemand par M. CAMILLE DARESTE, Ann. des Sciences Nat., 1851, 3me Série.

[2] Les Vers Cestoïdes ou Acotyles, considérés sous le Rapport de leur Classification, de leur Anatomie et de leur Développement. Par P. J. VAN BENEDEN. Bruxelles 1850, avec 26 Planches.

The *Annelida*, in a much more marked degree than the Entozoa and Echinodermata, are characterized by the possession of two distinct systems of nutrient fluids, of which one consists of the proper and true-blood, circulating definitively in perfect and closed vessels; the other, of a liquid mass, filling, in nearly all instances, the peritoneal cavity, and corresponding with, as it is the linear continuation of, that which, in the Entozoa and Echinoderms, was distinguished as the chylaqueous fluid. In the Annelida this peritoneal fluid is charged with corpuscles, which in different genera are sufficiently dissimilar to constitute significant generic characters, and these differences are even traceable to different species of the same genus. As in other classes, so in the Annelida, upon these two fluids two distinct and separate physiological functions devolve; each is essential to the maintenance of life. The history of the chylaqueous fluid and that of the blood-proper will be studied in this class with more minuteness than in the former, for it seems not a little probable that the "tangle unravelled" by the study of these fluid elements of nutrition in the Annelids will conduce to more exact views than those now prevalent in physiology with reference to the mechanism of nutrition in all invertebrate animals.

All the recesses and ramifications of the general cavity of the body in the Annelids communicate freely with each other, constituting thus one common space. This space is lined by a distinct membrane, which is obviously the anatomical analogon of the peritoneum, and is filled by a fluid which is *unquestionably an organic fluid*. In the Annelida the peritoneal membrane is not vibratile, the oscillations of the fluid contents cannot therefore be due to ciliary vibration. This fact distinguishes the Annelids from the Echinoderms, Medusæ and Zoophytes: it further proves that the movements of the chylaqueous fluid are not in ALL cases dependent on the presence of cilia. The rule is suspended in this class. In *Glycera alba*, and in one or two other species, however, the peritoneum where it penetrates the appendage is lined by vibratile cilia. Anteriorly to the researches herein recorded, I am not aware that any anatomist has recognised the real physiological meaning, or described the true histological characters of the chylaqueous fluid in the Annelida. In the historical introduction to this paper I have already indicated the extent to which the researches of M. QUATREFAGES have proceeded in that direction. To him undeniably belongs the credit of having *independently* determined the fact of the existence of 'a fluid' in the visceral cavity of the Annelid. The first publication of his generalized results occurs in the Annales des Sciences Naturelles for 1852. The results of my dissections, announcing the existence of a chylaqueous system of fluid in the Annelida, were first made public at the Meeting of the British Association, which was held at Swansea in the year 1849. It was not until this year (1852) that I became acquainted

ence to, *the fluids*. The light already reflected on the question of their organization, which has so long remained unanswerable, has rendered the *habitats*, unusual though they be, affected by these eccentric beings, no longer an *arcanum*, a theme of superstitious wonder, in physiological science.

with the more recent contributions of M. QUATREFAGES towards the study of the difficult subject of the anatomy of the Annelida. In the analysis of his memoirs* I have endeavoured conscientiously to assign to the versatile genius of this French naturalist the real merit with reference to this subject to which it is entitled. I have shown, I trust correctly, to what a very limited distance the parallelism continues between both the researches and the conclusions of M. QUATREFAGES and my own.

One important difference between our observations, severally, should be here unequivocally defined. He states that in *all* Annelida the "fluid of the visceral cavity" is circulated by means of the vibratile cilia by which the cavity in question is lined. I have affirmed the very contrary of this statement as the *uniform* result of my investigations. In no Annelid whatever, the Aphrodite excepted, is the cavity containing the chylaqueous fluid lined by vibratile epithelium. Cilia exist on the *internal* hollows at the bases of the feet, and on the tentacles of *a few* species only.

It is only possible in the larger species to obtain a sufficient quantity of the peritoneal fluid for the purposes of chemical analysis. In *Arenicola, Terebella nebulosa, T. conchilegia,* and the largest Nereids, it may be readily collected for examination. In these species it exceeds sea-water in specific gravity, being from 1·032 to 1·034, the water from which they were taken being 1·028. Salt water being the basis of this fluid in the Annelida, the superaddition to it of fluid and solid organic principles accounts for the high density of the peritoneal fluid in these animals. On standing a distinct coagulum is precipitated, carrying with it the corpuscles. By the coagulum the presence of fibrine is announced, and that of albumen is distinctly proved by the addition of nitric acid; slow evaporation yields a rich crop of the cubes and octahedra of the chloride of sodium. The morphotic elements vary in a remarkable manner in different species; that is, for the same species, the individuals being different, the corpuscles of the chylaqueous fluid are *constant,* and *nearly* the same in microscopic characters for *every* season of the year. In different species therefore these solid elements of this fluid, like the corpuscles in the blood of vertebrated animals, become signs of specific distinction, but the specific variations are much less marked than the generic. In the case of the Annelids, it is susceptible of demonstration that the floating cells of the chylaqueous fluid vary in apparent *structural* characters with the *age* of the individual. For some time after the emergence of the young from the ovum and before the development of the branchial, pedal, and tentacular appendages, the chylaqueous fluid is a limpid, transparent, *non*-corpusculated liquid. It bears not a trace of floating corpuscles. This fact is full of interest. As the worm progresses in growth, so the corpuscles slowly appear in the chylaqueous fluid. The blood and the blood-system are produced *before* the floating cells are generated in the chylaqueous fluid. The conclusion is evident. In the young Annelid the agency of the floating corpuscles of the chylaqueous fluid is *not required* either for the elaboration of the fibrine or the production of the pigment of the blood-proper. But it is important to guard against

* See *ante*.

the apparent continuation of this inference, that what is true of the young is so also of the old. In relation to the history of the solid elements of the chylaqueous fluid in the Annelids, another fact of equal value and significance with the former may here be mentioned. For some time before the death of the old worm, whether the death take place by fission of the body into fragments, or by general decay and decomposition, the corpuscles of the chylaqueous fluid go on gradually disappearing. The ova and sperm-cells accumulated in the fluid of the visceral cavity during the season of reproduction, also supersede, to a great extent, the proper corpuscles of this fluid. At this period however the blood-system acquires a very conspicuously augmented development.

In studying the histology of the solid elements of the fluids in the Invertebrata, it is desirable to forearm the observer with one admonition. When these bodies dehisce under the eye in the field of the microscope, the semifluid contents are projected out in strings or filaments; the highly fibrinous fluid contained *in* the cells *coagulates as it escapes*. This appearance has deceived some observers into the supposition that such cells are *ciliated*, epithelial, self-motive bodies. They are not so. I have ventured to estimate this frequent fact as a direct demonstration of the theory advocated by some physiologists, that the floating cells of the fluids *secrete* a self-coagulating principle. But at the present stage of this inquiry the question admits of no reply, whether the mode indicated is *the only process* by which fibrine is generated in the living fluids? It is probably not so. My present conviction is that fibrine, at all events in the vital fluids of the invertebrated animals, MAY be evolved in a non-corpusculated fluid, in virtue of a zoo-chemical process enacted by the liquid *per se*.

Let us now proceed to a detailed description of the corpuscular elements discoverable in the chylaqueous fluid of the principal families of the Annelida.

In *Arenicola Piscatorum* the chylaqueous fluid is very abundant; the cavity in which it is contained is scarcely at all partitioned by segmental septa. The floating cells of the fluid in this worm are relatively numerous and very liable to dehisce, producing digitate, fibrillated, ciliated, stellate and other forms of bodies. These accidental appearances must be discriminated from the entire unbroken cells (fig. 14). These latter are orbicular in figure, bearing a nucleus and filled with minute granules. They are very liable to cohere together into round agglomerated masses (fig. 14 *a*). As the process of evaporation proceeds crystals of chloride of soda appear (fig. 15). In the young *Arenicola* the peritoneal fluid is less abundantly corpusculated and colourless (fig. 31). In the old animal also the corpuscles disappear. During a considerable part of the *summer* ova and sperm-cells abound in this fluid; they should be carefully distinguished from its proper corpuscles. In *Arenicola* the blood-proper is exclusively *aërated*. The integuments bounding the visceral chamber are too dense to admit of any agency of the surrounding medium on the fluid contained within. Under such circumstances the physiologist must admit one of two suppositions. The chylaqueous fluid, *being a vital fluid*, must in *some* manner be oxygenized. In this case this can happen

only *indirectly*, either through the blood-proper, which in this species immediately receives oxygen from without, or through the alimentary system, which is being constantly traversed by a current of fluid-sand. These facts are here noticed in historic connection with the chylaqueous fluid, because they tend to elucidate its peculiar laws.

Between the corpuscles of the chylaqueous fluid in *Nais filiformis* and those of *Arenicola*, a close resemblance is observable, the same disposition to fibrillate on bursting. The typical cell is orbicular in shape, nucleated and granular (fig. 16). Another and more embryonic variety presents only a nucleus, the granules being wanting. In *Nais* the chylaqueous fluid is colourless, and considerable in volume; it is the 'bed' on which the intestine moves. In the several species of the genus *Nais*, these corpuscles present very palpable diversities of shape, though not of structure. There are no external organs in this genus, either for the exposure of the chylaqueous fluid or blood-proper to the aërating element. As the latter is centrally situated, and therefore embraced by the former, it is manifest that the chylaqueous fluid is the more *directly* affected of the two by the external oxygen. The peculiar disposition of the vessels in *Nais* renders this inference only the more probable.

In *Sabella vesiculosa* (fig. 17), and in a less marked degree in *Sabella alveolata*, the general cavity of the body is filled with a fluid, the cells floating in which incline to a uniform spindle-shaped form. Those which are spherical appear to be only the immature phase of the former variety, and between the two there are several intermediate grades. They are almost wholly devoid of internal molecules, being filled with a fluid held together by a capsule of determinate form. In this species, as in the succeeding, the chylaqueous fluid plays no direct part in the office of respiration.

In *S. alveolata* (fig. 18) the chylaqueous fluid is less marked in volume; its corpuscles are spherical and granular, abounding in non-nuclear oleous cells. The blood-system is highly developed. The intestine is tied to the integument by frequent septa.

The splanchnic cavity in *Sabella à sang vert* of M. Edwards contains a colourless corpusculated fluid, the cells floating in which are less uniform in size and figure than the corresponding bodies in the preceding species. They are generally observed under the form of small orbicular cells, becoming flattened as they grow older, and unevenly outlined; many of them exhibit that curious tendency to protrusion of the cell-capsule which so frequently characterizes the corpuscles of the chylaqueous fluid. They are all more or less charged with molecules of oleine of high refractive power (fig. 19). In this species, as first discovered by Milne-Edwards, the true-blood is grass-green in colour. The branchial appendages, cephalically situated, and pectinated in form, are penetrated by the latter fluid, very little, if at all, by the former. In this species the chylaqueous fluid is excluded from all direct participation in the process of aëration.

As respects the corpuscular elements of the peritoneal fluid, the *Terebellæ* are more remarkably characterized than any of the preceding species of the Annelida. In the two species, most familiar to us on the coast of Swansea, the chylaqueous fluid is very large in amount. It is a thick, milky liquid, containing large compressed oval cell-capsules, almost individually visible to the naked eye. These corpuscles are not nucleated cells, but flattened vesicles filled with oil-molecules and granules. The cell-capsule is extremely *attenuated*. Others of these large cells seem to consist only of lesser cells aggregated together into circular groups. Interspersed between these bodies may be seen another variety very different from the former. They are chiefly seen in the hollow axes of the tentacles moving to and fro, and in figure uniformly spindle-shaped, destitute of visible contents and pellucid (fig. 20). Those of *Terebella conchilegia* (Plate XXXII. fig. 21) are about one-half the size of those of this fluid in *Terebella nebulosa* (fig. 20). In all other microscopic characters the latter are exactly like the former.

The respiratory process in the Terebellæ is divided in an equal proportion between the chylaqueous fluid and the blood-proper. Each tentacle is traversed by a blood-vessel and by a current of chylaqueous fluid. The visceral cavity of the Terebellæ at the reproductive season is filled with ova and sperm cells. In this genus the mass of the chylaqueous fluid is an important agent in locomotion.

The structure of the common earth-worm is distinguished in several material respects from that of those Annelids forming the subject of the preceding remarks. In *Lumbricus* the segmental partitions are complete and well-marked, tying, at very frequent intervals and intimately, the intestine to the integument, and consequently limiting, almost obliterating the peritoneal cavity. This cavity however does exist, and contains a viscid colourless fluid, bearing spherical, nucleated and granular cells (fig. 22), intermingled with pellucid cellules, which appear only to represent the immature phase of the former. These corpuscles seem to me to be the bodies which Mr. WHARTON JONES has mistaken for those supposed to exist in the blood-proper*. The fluid of the peritoneal cavity is of almost momentary importance to life in the Earth-worm. Kept in a perfectly dry atmosphere even for an hour it dies. It cannot be revived; and is covered by a slimy fluid which appears as if it were that of the peritoneal cavity exuded. In the adult state in this worm the system of the blood-proper is highly developed; a circumstance which explains the diminished proportion of the chylaqueous fluid. That the *basis* of this latter fluid consists of water, I infer from the immediate importance of moisture to life. The fact of its existence, and next that of its physiological importance, are quite proved by the results of observation on the young Earth-worm (fig. 23). In the early stage of development the peritoneal fluid in this worm is, relatively, considerable in quantity. In the infancy of this Annelid it fulfils those functions which during adult life are discharged by the true-blood. The peritoneal fluid in the young abounds in spindle-

* Philosophical Transactions, Part II. 1846.

shaped bodies, which are not to be found in that of the adult. In this worm the chylaqueous fluid is not submitted to the process of aëration.

In *Œnone maculata* the chylaqueous fluid, which at the reproductive season is large in quantity, is charged thickly with corpuscles (fig. 24) of one uniform size and figure, and too minute to fall within the defining power of the microscope. They are mere amorphous molecules. In these worms the chylaqueous fluid is not concerned in respiration. The branchiæ bear only proper blood-vessels.

In the case of the Borlasiadæ, Planariadæ and Liniadæ, the chylaqueous fluid is contained in the digestive cæca and diverticula. In some of the Planariadæ, however, I have proved that a space does actually exist between the digestive diverticula and the solid structure of the body, *which is lined by a vibratile epithelium,* and into which probably the external water is in some way admitted. By this water, thus situated, the contents of the digestive cæca are aërated. The fluid oscillating in these cæcal appendages of the stomach is thickly charged with corpuscles, which from their regular character prove this fluid to have already reached a high standard of organization. They occur as elliptical cells in the *Borlasia* from which the illustration (fig. 25) was taken; the fluid abounded also in small orbicular points, constituting the 'molecular basis' of the digestive product. In this worm it is this fluid, and not the true-blood, that is aërated; the latter system is too little developed.

The genus *Phyllodoce* is characterized by the existence of a peritoneal fluid, highly organized and corpusculated, and contained in a space which is almost undividedly continuous from one end of the body to the other; the intestine being tied to the integument by means of bands, which leave the fluid free room to play from one segmental compartment to the other. In *P. lamelligera* the peritoneal fluid is colourless, and contains flattened circular corpuscles, bearing a centric nucleus and filled with oily molecules (fig. 26). Cells of a pellucid character, and much more diminutive than the former, make up the mass of the morphotic elements. In the genus *Phyllodoce* the branchial organs are not at all penetrated by blood-vessels. The chylaqueous fluid, by which their areolæ are distended, must therefore be the direct recipient of the external oxygen.

The *Nereid worms* are all distinguished by the existence of a large amount of chylaqueous fluid in the visceral cavity. The septa of the segments are not complete partitions; the fluid therefore fluctuates with freedom from one end of the body to the other, and assists in a very material degree the locomotion of the worm. In this genus the fluid is characterized by the presence of corpuscles of large comparative size, and of generally an irregular figure (fig. 27). In the season of autumn, as in some other Annelids, these corpuscles, which are the proper solid elements of the fluid, are superseded by true ova, one of which is represented in the centre of the figure. The peritoneal cavity in these familiar worms is always filled with a milky fluid, the organic quality of which cannot for a moment be doubted. The blood-proper is red, but fluid, that is, non-corpusculated, and the blood-system of vessels

is elaborately developed. In the larger species the parietes of the feet are embraced in a framework of reticulate blood-vessels; but the interior of these appendages, which is hollowed into a cavity, filled with the peritoneal fluid, proves that both systems of fluids participate equally in the process of respiration. These worms are the most active in their habits of all Annelids, which results probably from the perfection of their circulating system.

In the genus *Spio** the chylaqueous fluid is subordinate in amount and importance. Its corpuscular elements are imperfectly developed. They are opake milky globules, possessing sometimes a nucleus, and sometimes none: they are almost entirely destitute of granules. In these elegant worms it is the blood-proper system that usurps the office of respiration. The branchiæ convey into contact with the surrounding element very little of the chylaqueous fluid. It is held in the areolæ of the membranous appendages attached to the branchiæ (figs. 28).

In *Nephthys Hombergii*, though not conspicuous, the chylaqueous fluid is considerable in volume. Its motions are limited in consequence of the frequent bridles by which the intestines are tied to the integment. Its corpuscles (fig. 30) are relatively scanty. They are spherical in form, and filled with secondary molecules. The oleous globules which accompany them are numerous. The inferior importance of the chylaqueous system in these worms is compensated by the highly evolved condition of that of the blood-proper. The branchial processes, which are hollow, are filled with a coil of vessels, and with a stream of chylaqueous fluid; both fluids therefore in equal proportions are submitted to aëration.

Of the corpuscles of the peritoneal fluid in the genus *Glycera* (fig. 31) there is this extraordinary fact to be related, that they are *blood-red in colour*, and not unlike in figure and size those of the blood of Reptiles. In this beautiful worm the *true-blood* conforms with the Annelidan law of perfect fluidity; it bears no visible elements, and is light red in colour, the colouring element, as in all other Annelids, being *dissolved* in the fluid mass. It is remarkable that the *fluid* contents of the visceral cavity in *Glycera* should be *colourless*, while the corpuscles which it holds in suspension should be filled with a blood-red liquid, contrasting these bodies in a striking manner with the fluid in which they float. The cavity of the peritoneum is disproportionately capacious. It is little interrupted by segmental septa. The worm is extremely quick and active in its movements. The *true branchiæ* are hollow cylindrical appendages, lined *within* and *without* by vibratile epithelium, and penetrated only by the fluid of the peritoneal cavity. *They are supplied by no true-blood-vessels. The chylaqueous fluid therefore is the subject of the respiratory change, for which these appendages present an appropriate mechanism.*

To this fact the highest interest attaches. It constitutes an undeniable proof that the fluid of the peritoneal cavity *is capable of* discharging the highest function of the animal organism. The presence of *red* corpuscles in the fluid of *this* species does

* Of which three species are found on the coast of Swansea.

not prove that in no other species is this fluid capable of enacting a true respiratory function, since the branchial organs of nearly all Annelids (many by it exclusively) are more or less injected by the fluid of the visceral cavity. On the other hand, a fluid which is destitute of corpuscles may also perform the office of respiration. Floating cells are *not* therefore essential to this process. In *Glycera alba* (fig. 31) the red corpuscles are almost uniformly oval in figure, the oval being compressed, slight, and sometimes a little curved or distorted. These bodies bear nothing in their interior but a red fluid, and a nucleus which is elliptical in shape and very indistinct. An instance here and there occurs in which a few molecules are contained in these cells. WHY the corpuscles of the chylaqueous fluid of this worm and of *Matuta clymenoida* (WILLIAMS) (fig. 33) should, contrary to the universal Annelidan rule, contain a pigmented fluid, it is at present difficult to explain.

In a species of marine (fig. 32) *Nais*, common on this coast, which I have named *N. maculosa*, the corpuscles of the peritoneal fluid are spherical cells filled with granules, the latter being grouped in the centre, and separated from the involucrum by a layer of limpid fluid.

Fig. 33 gives another illustration of the bodies found in the peritoneal fluid of the Annelida. They are those of a worm which I have called *Clymene arenicoida**. Fig. 34 represents those of this fluid in *Sigalion Boa*. In the genus *Polynoë* the peritoneal fluid exists in large quantities. In all species it is richly corpusculated and milky. The blood-system in *Sigalion* is subordinate. The blood-proper is colourless and incorpuscular. The branchial appendages are constructed like hollow tubes, with express view to expose the peritoneal fluid, and *not* the blood-proper, to the aërating agency of the surrounding element. The corpuscles figured (fig. 34) resemble those of scaly epithelium. They are pregnant with molecules and oil-cells. Fig. 35 illustrates another variety of these bodies, from the peritoneal fluid of a new worm, which I have named *Matuta clymenoida*. These corpuscles are bright red, like those of the chylaqueous fluid of *Glycera*. They are very abundant, and give to the whole worm a blood-red colour. They assume the form of flattened scales, bearing two or three molecules and sometimes a nucleus, being, from the scantiness of their contents, transparently delicate and filled with a red fluid.

The contents of the peritoneal cavity of *Aphrodita aculeata* (fig. 36) approach more nearly to those of the Echinoderms than of the Annelida. It must be remembered, with reference to this Annelid, that the water which is admitted underneath the *dorsal felt* is quite distinct from that contained in the cavity of the peritoneum. The former is erroneously described by all naturalists as corresponding with that found in the visceral chamber in the Echinoderms. It is the *latter* and not the former fluid which is the true homologon of the chylaqueous fluid of the Echinoderm.

* A full description of the specific characters of these new species will be found in my Report on the British Annelida, Transactions of the British Association, 1851.

Like that of the latter it abounds little in organic corpuscles, and the general appearance is like that of pure water. The morphotic elements consist of groups of formless granules. The diverticula of the digestive system are so arranged as to be surrounded within by the peritoneal fluid and without by the external water, which is drawn in through the meshes of the felt. This arrangement proves obviously that the contents of the digestive cæca are *expressly* in this Annelid exposed to the action of the *two* fluids described. These 'contents' consist of a dark olive fluid, and though destitute of organic bodies, is endowed with nutritive properties.

In *this Annelid*, therefore, *as in the Leech*, the fluid contained *in* the digestive sacculi is the true equivalent of the chylaqueous fluid of the peritoneal cavity of other species. In the Leech this latter cavity is almost obliterated, in *Aphrodita* it is spacious and occupied by a fluid, colourless and limpid as water. Moreover, in *Aphrodita*, the peritoneal cavity is distinguished from that of ALL other Annelids by the fact that it is lined by vibratile epithelium, in which respect it is allied to the Echinoderms. The fluid which fills the digestive cæca in *Aphrodita* contains no determinately *organized* solid bodies, another respect in which it resembles that of the diverticula of the stomach of the Starfish. The blood-proper in this aberrant Annelid is perfectly fluid, devoid, that is, of all morphotic elements, and yellowish in colour.

In no case in the animal kingdom is the physiologist presented with a more favourable opportunity for determining the real meaning of the floating cells of the nutritive fluids than that which occurs in the Annelida. Here nature performs for him the difficult experiment of separating the albumen and fibrine-producing from the colour-producing parts of the vital fluids. It has been demonstrated that in every Annelid the chylaqueous fluid is more or less corpusculated. In every species this fluid and its corpuscles have been found to be *colourless*; two exceptions only in the whole class were encountered. The chylaqueous fluids of *Clymene arenicoida* and *Glycera alba* were found to be charged with blood-red corpuscles, the fluid in which they floated being *colourless*. Here is an unequivocal demonstration that the *involucrum* of the floating cell is capable of separating from a *colourless* fluid a pigmented fluid, the blood-red contents of the cells! But what can become of the red fluid with which these floating cells are filled? If the cells dehisce while yet in the chylaqueous fluid, the latter ought to exhibit a tinge of the same colour, which is not the case. Further observations are required to track with accuracy the vicissitudes which these singular bodies undergo, but which are singularly calculated to unfold the tale of the real changes which all floating corpuscles are destined to suffer in fulfilment of their peculiar functions.

Blood-proper in the Annelida, and its physiological relations.—CUVIER, LAMARCK, DE BLAINVILLE, PALLAS, SAVIGNY and MILNE-EDWARDS, amongst continental naturalists, have contributed observations on this subject. The discovery of red blood in

these animals became with Cuvier the ground of classification, "Frappé de la couleur si remarquable du liquide nourricier chez ces animaux, il les désigna d'abord sous le nom de Vers à sang rouge."

Lamarck also viewed the red blood of the Annelida (a name now first devised and applied by him) as an essential distinction of the class*. It was observed at this time by M. de Blainville, that in *Aphrodita aculeata* and *Herissa* the blood was colourless†. M. Pallas had however anticipated both Cuvier and De Blainville in these observations, as well as in that of the existence of red blood in many of the Annelida‡. To the laborious researches of Milne-Edwards the zoologist is indebted for a full and complete history of the *colour* and distribution of the blood in the Annelida§. It is however remarkable that an observer of such proverbial accuracy should have overlooked the question relating to the *structure* of this fluid. Remarking that in the *Euniciadæ, Euphrosinidæ, Nereidæ, Nephthys, Glycera, Arenicola, Hermella, Terebella, Serpula, Lumbricus, Hirudo*, &c., the blood is of a red colour, he proceeds, "Mais, du reste, examiné au microscope, ce liquide ne m'a pas semblé différer du sang des autres animaux sans vertèbres. Les globules qu'on y voit nager n'ont pas du tout l'aspect de ceux propres au sang des animaux vertébrés : ce sont des corpuscules circulaires dont la surface a une apparence framboisée et dont les dimensions varient extrêmement chez un même animal‖." From the direct expressions used in the above passage, it is manifest that Professor M.-Edwards admits the existence of "circular corpuscles" in *the blood* of the Annelida, which according to his description, present the appearance of raspberries, varying much in dimensions in the same individual.

In his learned memoir¶ in the Philosophical Transactions (1846), Mr. Wharton Jones describes and figures the blood-corpuscles (*sic*) of the Earth-worm and the Leech, and defines, in the following terms, the mode in which the samples submitted

* "Ce qui a effectivement paru très singulier, ce fut de trouver que les Annelides, quoique moins perfectionnés en organisation que les Mollusques, avaient cependant le sang véritablement rouge, tandis que celui des Mollusques, des Crustacés &c., n'a pas encore cette couleur qui dépend de son état et de sa composition, et qui est celle du sang de tous les animaux vertébrés. On sent bien que, parmi les animaux que nous rapportons à notre classe des Annelides, ceux qui se trouveraient n'avoir pas dans leur organisation le caractère classique, n'infirment point ce caractère et ne sont placés ici qu'en attendant que leur organisation soit mieux connue."—Lamarck, Animaux sans Vertèbres, t. v. p. 276.

† Art. *Vers*, du Dictionnaire des Sciences Naturelles, t. lvii. p. 409.

‡ See his Miscellanea Zoologica, p. 89. "Sectis in dorso longitudinaliter tegumentis, occurrit vasculum lympha sæpe turbidula plenum." From this sentence it is much more probable that in this section Pallas merely opened the great cavity between the intestine and the integument, out of which the lympha turbida escaped, and that it was not the blood-proper, as Milne-Edwards supposed, that Pallas described, but the fluid occupying the peritoneal cavity.

§ Recherches pour servir à l'histoire de la circulation du sang chez les Annelides, lues à l'Académie des Sciences le 30 Oct. 1837.

‖ Annales des Sciences, 2me série, Oct. 1848, 'Circulation dans les Annelides,' par M. M.-Edwards.

¶ The Blood-corpuscle considered in its different Phases of Development in the Animal Series, by T. W. Jones, F.R.S., Philosophical Transactions, Part II. 1846.

to examination were obtained:—"The blood was most readily obtained for examination from the abdominal vessel, but in extracting it care was required against its becoming mixed with the secretion poured out from the skin in great abundance when the animal is wounded," p. 94. Mr. JONES then observes, "The corpuscles of the blood of the Earth-worm *are remarkable for their great size*, being on an average $\frac{1}{1100}$th or $\frac{1}{1200}$th of an inch in diameter. They are both granular and nucleated cells." Thence this author proceeds to an elaborate account of the metamorphoses which these two varieties of corpuscles undergo. And with reference to the Leech Mr. JONES affirms, "that *while* the corpuscles of the blood of the Earth-worm are the largest which I have yet found in any invertebrate animal, the corpuscles of the Leech are the smallest," p. 95, *op. cit.* Investigations on an extended scale, and conducted with the strongest desire for the real truth, enable me in this place to state most confidently that in the descriptions cited, both from M. MILNE-EDWARDS and Mr. WHARTON JONES, these distinguished observers have fallen into the most extraordinary errors. *In no single species among the Annelida does the blood-proper contain any morphotic elements whatever*! In all instances, without exception, it is a perfectly amorphous fluid, presenting under the highest powers of the best microscope no visible corpuscles or molecules or cells of any description whatever. It is a limpid liquid variously coloured, as formerly and correctly stated by MILNE-EDWARDS, in different species.

In a memoir* recently published, M. QUATREFAGES has re-traversed the ground first opened by MILNE-EDWARDS. M. QUATREFAGES confirms, without a single exception, the conclusions at which his colleague had previously arrived. Historic truth demands it to be stated that M. QUATREFAGES, in the memoir cited, has improved very little upon the original description of MILNE-EDWARDS, and in that little he has become entangled in error.

In the *Arenicolæ* and *Eunice* he describes proboscidian and branchial hearts, which do not exist. M. QUATREFAGES seems to have doubtfully recognised the general fact of the *fluidity* of the blood-proper of the Annelida. He cites however in the same paragraph such striking exceptions to this fact, that he gives no proofs whatever of having mentally realized the *law* which demands that the true-blood of the Annelida *should be invariably fluid*, non-corpusculated, *because* in this class the office which devolves upon the floating cells is performed in the chylaqueous fluid, where alone such cells exist. This remarkable principle, which literally divides the nutritious fluid into two parts, upon one of which the corpuscular agency devolves, upon the other the more special duties of solid nutrition, seems not in the least degree, at any time, to have entered the mind of M. QUATREFAGES.

"Dans deux espèces de Glycères de la Manche, qui toutes deux sont assez communes à Saint-Vaast, j'ai trouvé un sang fortement coloré en rouge par des globules

* Études sur les types inférieurs de l'embranchement des Annelés, sur la circulation des Annélides. Annales des Sciences Naturelles, 1850.

parfaitement distincts et réguliers. Le liquide lui-même était incolore. Ici les globules offrent la plus grande ressemblance avec ceux des Vertébrés. Ce sont de petits disques aplatis de $\frac{1}{120}$ de millimètre environ," &c. In this statement M. QUATREFAGES is incorrect in attributing these 'globules' to the blood-proper, for the blood of this worm, like that of all Annelida, is destitute of every kind of globules; it is perfectly fluid. The corpuscles exist only in the chylaqueous fluid, but the description of them, as conveyed in the preceding quotation, is by no means exact.

In general no distinction into venous and arterial blood is detectable, the *plan* of the Annelidan circulation rendering such a distinction almost impossible. The colouring elements are in all cases fluidified and uniformly blended with the fluid mass of the blood. The colour therefore must be developed in the *fluid*-mass, and *that too without the intervention of any corpuscular* agency, since the true-blood, as already stated, contains NO solid cells.

Glycera alba and *Clymene arenicoida* only excepted, the corpuscles of the chylaqueous fluid in ALL Annelids are destitute of colour. It is not chemically impossible that the coloured ingredients may exist in this latter fluid in a colourless state of combination, and that these ingredients, through entering into new combinations, may become brightly coloured after transition into the true-blood.

In consequence of the impracticable minuteness of the quantity, no direct chemical analysis of the blood in the Annelid can be executed. As to the *colour*, however, analogy removes all doubt that the red tinge is due to the salts of iron and the green to those of copper. In those species of which the blood is light yellow, opake, milky, or lymph-like, it does not follow that the salts of the coloured minerals are altogether absent: they may exist under *colourless* combinations. To the physiologist it cannot be unimportant in this place to demand, if the blood-proper of the great majority of Annelids be a non-corpusculated limpid *coloured* fluid, and the chylaqueous fluid a colourless corpusculated liquid, in what manner, by what agency, does the blood acquire its colour? If it be destitute of floating cells, the production of the pigment cannot be ascribed to the agency of the latter bodies. And if this pigment do not, at all events in a visible form, exist in the chylaqueous fluid, it must be developed during the passage of the latter into the blood-vessels (for, as will be afterwards more fully explained, the contents of the blood-proper system are derived by direct absorption from the great reservoir of the chylaqueous fluid). From the obviously connected sequence of these events the inference is clearly deducible, that the parietes of the blood-vessels impress upon the fluid *in transitu* a chemico-vital change, which eventuates in the evolution of pigment. In other language, the walls of the *blood-vessels*, under the circumstances indicated, accomplish what in the instances of *Glycera alba* and *Clymene arenicoida*, and it may be prophetically added in all Vertebrata, is performed by the *involucra*, the cell-capsules of the floating corpuscles. One other lesson of extreme value is read to the zoo-chemist by the history of the blood in the Annelida. It is a limpid, non-corpusculated coloured fluid. In many species it

alone is submitted to the process of aëration. *Therefore* the agency of the floating corpuscles is not essential to the respiratory action of oxygen on the blood. This fact, which is unequivocal, is promissory of future discoveries.

Relation between the Blood-proper and Peritoneal Fluid.—The physiologist cannot view with unconcern the question which relates to *the mode* in which the two fluids now described in the *Annelida* stand related to each other. It is scarcely required to observe, that what applies under this head to the Annelida will prove no less applicable to the Entozoa and Echinoderms, in which also these two varieties of nutrient fluids coexist in the same individual.

In *all Annelida* a peculiar and express disposition of the blood-vessels is observable, by which an extensive contact is secured between the blood-proper and the fluid of the visceral cavity. This arrangement is so strikingly a provision for the attainment of a particular object that it cannot be misinterpreted. In the anatomy of the *Nais* this is perfectly and beautifully seen. From the sub-ganglionic trunk long coiled vessels proceed, describe several convolutions in the midst of the fluid, and in a *perfectly naked* and unsupported state, curve dorsally, still surrounded by the chyl-aqueous fluid, and empty themselves into the great dorsal trunk. In *Nais maculosa* (WILLIAMS) this distribution of the coiled vessels is still more readily demonstrated, in consequence of the bright red colour of the blood enabling the observer to trace the minutest vessels throughout their entire course. With respect to these vessels there is one remarkable fact to be stated, namely, that they maintain their singleness or individuality from their point of origin to their termination; they do not branch. In this fact is seen a beautiful provision against injury during the contractions and elongations of the body. The slender column of blood contained in these vessels, is directly and throughout its whole course exposed to the agency of the peritoneal or chylaqueous fluid. The agency of this fluid is obviously of a two-fold character; it first replenishes the blood-proper with the *chylous* materials by which its healthy constitution is maintained, in other words, the coiled vessels *absorb* a chylous pabulum from the peritoneal fluid; this process of chyle absorption may not be *exclusively* confined to these vessels; those distributed over the parietes of the intestine may participate in this function; and, secondly, the peritoneal fluid acting as a reservoir for the oxygen of the *external* element, forms *to* the coiled vessels a true aërating medium, the process of *breathing* being thus *internal.* In its application to the *Entozoa* this view of the mechanism of respiration acquires the highest interest. It is the *true method* of respiration in all *Entozoa.* The physiologist will now I trust definitively comprehend the breathing function in these parasites, *though destitute of all semblance of external organs of respiration**.

One more question remains to be considered, What is the physiological meaning of this *methodical contact* between the two fluid elements of nutrition in the *Annelida*? That the blood-proper in degree of *organization* (vitality) is higher than the chyl-

* In another communication I hope to enter at length into the demonstration of this subject.

aqueous fluid, no doubt can exist; and as already maintained, the true-blood is reproduced, at all events in part, out of the materials supplied by the chylaqueous fluid; the conclusion is obvious that this latter fluid *is* incipient blood, and that consequently it must be gifted *pro tanto* with the property of nourishing the solid structures of the body. But this inference is rendered almost certain by the force of the examples furnished by the Zoophytes, Medusæ, &c., in which this fluid constitutes the *only fluid element of nutrition* in the organism.

The chylaqueous fluid must however be regarded as in itself a manufactory; ITS corpuscles execute an office by which the mineral substances and proximate principles are vitally assimilated. In the Annelida (and therefore in the Entozoa and Echinoderms) the corpuscles do in THIS FLUID, as already explained, what in the higher Invertebrata and Vertebrata is accomplished by corpuscles, somewhat more definitively organized, floating in the true-blood. From these facts the physiologist may state, that *under all circumstances, how simple soever the fluid may be, the agency of cells*, either in the solids through which the fluids pass, or floating in the fluids themselves, is more or less essential to the vitalization of the liquid medium of nutrition. In the Annelida the true-blood is *incorpusculated, because* the cell agency is performed in the fluid, lower in grade than itself, which oscillates in the peritoneal cavity. If *this* fluid did not exist, then the corpuscles, solid cells, would probably have been present in the true-blood, there to enact their destined functions.

From these observations the inference may be drawn, that between these two nutritious fluids, in the zoological series, there obtains a definite physiological balance; that one is capable of absorbing or merging into the other, according as the observer ascends or descends the scale. The chylaqueous system ends above with the larva of Insects, and the true-blood system traced downwards terminates at the Echinodermata.

With reference to the nature of the function executed by the floating cells of the vital fluids, I may be permitted to mention here *one fact*, which, during the prosecution of my recent studies, has excited in my mind a constant and eager attention. When the voluminous corpuscles of the chylaqueous fluid of the Annelida *burst* in the field of the microscope, the semi-fluid contents of these bodies *fibrillate*, i. e. *coagulate as they flow out of the containing cells*. This is a constant fact observed with the utmost exactness a thousand times. It is an absolute proof, addressed directly to the eye, that the contents of the cells, that which they themselves *secrete*, is a self-coagulating principle, is higher in organic properties than that in which the cells float, and which surrounds them externally, and out of which therefore their parietes *must* produce what their cavities circumscribe. Science does not demand a more satisfactory proof that the floating cells have for *one* of their offices that of generating *fibrine*; another of their functions is that unquestionably of manufacturing pigment.

Articulated Animals.—Arranged on the basis of the evidence drawn from the

history of the fluids, the articulated classes come here into contact with the annulose series. In the embryonic condition of the Myriapod and the Insect, the circulating fluids present *all* the essential characters of the chylaqueous system, as already described in the economy of the Annelid. It is a fluid surrounding the rudimentary intestine, and moving *to and fro* in a spacious chamber, its movements being determined by no other power than the muscular contractions of the intestine on the one side, and the integuments on the other, by which the containing cavity is bounded. It is a veritable chylaqueous system. The dorsal vessel is yet *un*formed, the corpuscles of the fluid, scanty in those of the larvæ of many species, are temporary provisions, destined soon to be replaced by those permanent elements by which the blood of the perfect animal is afterwards to be distinguished.

When the embryo of the articulated animal first emerges from the ovum, it is virtually an Annelid in outward form and internal structure. The system of the nutrient fluids, and the fluids themselves, fall obviously under the character of the chylaqueous type. The perfect absence of independent conduits circumscribing a highly organized fluid, reduces the larva of the Insect to the low standard of the embryo Annelid. Here then is an unequivocal demonstration of the proposition that the articulated series are *directly* continuous with the annulose through the medium of the fluids; that the chylaqueous system is traceable from the latter into the former; that which is persistent in the Annelid is temporary only in the articulated animal. These generalizations are founded upon faithfully observed *facts*, the value of which in philosophical zoology cannot be exaggerated. In relation to the nutritive fluids of the articulated series, it is proposed now that we proceed to the establishment of the following propositions:—1st, that in the embryonic condition of the Myriapoda, Insecta, Arachnida and Crustacea, the fluids, in composition and plan of circulation, fall under the designation of the chylaqueous system which persistently prevails in all classes below the Articulata; 2nd, that although in the articulated animal the chylaqueous fluid and the blood-proper have in no instance a contemporaneous existence in the same individual, yet that these two orders of fluid are marked by such strikingly diverse physical characters that their distinctness and independence cannot be doubted; 3rd, that the corpuscles contained in the embryonic or chylaqueous fluid of the Articulata present varieties in form, structure and size, far different from and more numerous than those which occur in the corpuscles of the true-blood of the adult animals; 4th, that throughout *all articulated animals*, from the Myriapod to the highest Crustacean, the mature corpuscles of the true-blood conform unequivocally to one fundamental type of structure and figure, a novel demonstration of a new order of zoological affinities!

Myriapoda.—It was observed by Mr. NEWPORT that in the larva of *Iulus* the fluid filling the space around the intestine, for some days before the pulsations of the dorsal vessel, became detectable to the eye. The truth of this statement I have repeatedly confirmed. The fluid of the visceral cavity in the larvæ oscillates to and fro *before*

the development of any special power for directing and sustaining its movements. This fluid is at first almost destitute of floating cells, which consist only of oleous molecules. In process of growth corpuscles, more or less resembling those afterwards to be described as present in the blood of the adult Myriapod, begin to appear, and *pari passu* with this genesis of definitively organized corpuscles the structure and function of the dorsal vessel assume a more obvious presence. This embryonic system of fluid, before the appearance in it of the permanent corpuscles, and *before the development of the tracheal system*, undergoes the process of aëration in accordance with the plan on which this great function is performed under the chylaqueous type. Less complexly organized than the blood-proper, it demands no special apparatus for its exposure to the aërating medium. As it rolls in the general cavity of the body, it undergoes adequately this vital change. These observations require very little to be modified to render them true of all insect-larvæ. Thus, then, there exists in the Myriapod 'a circulating fluid' anterior to the true-blood, which the latter gradually supersedes, and 'a respiration' which precedes that which subsequently devolves upon the tracheal system*.

In the adult Myriapod the blood is colourless and richly corpusculated. The corpuscles are perfectly destitute of colour. This fact is true of the fluid systems of *all* articulated animals without a single exception. Wherefore this universal absence in the fluids of a pigment-producing faculty? The floating bodies of the blood in the adult Myriapod are regularly and determinately organized. They are *nearly* the same in the Iulidæ as in the Scolopendræ, the highest and the lowest orders. They present under the microscope, in a fresh drop of blood, three leading varieties:—1st, a large pellucid nucleus surrounded by a few granules (Plate XXXII. fig. 38); 2nd, the orbicular, in which the granules have grown in number, almost concealing the nucleus (fig. 39); and 3rdly, the ovoid or oat-shaped, in which the nucleus has reappeared (fig. 40). In none of these bodies is it possible under any manœuvre to detect the presence of a cell-capsule. The molecules surrounding the nucleus seem rather to be drawn to the latter by a mysterious centripetal power, than embraced by an involucrum. These bodies, when they burst in the field of the microscope, *fibrillate*, proving that the molecules are held together by a tenacious self-coagulating principle.

Insecta.—Contributions, from several authoritative observers†, towards a better understanding of the circulation of Insects, have appeared during the last two years.

* "The history of the development of the embryo of the Myriapod presents a remarkable resemblance to that of the true Annelid; for the embryo at the time of its emergence from the egg possesses but a very small number of segments; and these continue to increase by the repeated subdivision of the penultimate segment until the number characteristic of the species has been attained."—Principles of General and Comparative Physiology, by Dr. Carpenter, 3rd edit. 1851, p. 375.

† Etudes Anatomiques et Physiologiques et Observations sur les Larves des Libellules, par M. Léon Dufour, Annales des Sciences Nat. 1852. Nouvelles Observations sur la circulation du sang et la nutrition chez les Insectes, par Émile Blanchard, *op. cit.* 3me Série, 1851. Note sur la circulation des fluides chez les Insectes, par le Professeur Louis Agassiz, *op. cit.* 3me Série, 1851.

They relate however rather to the mechanism of the fluid's orbit than to the composition of the fluid itself. They cannot therefore be rendered subservient to the objects of the present communication. Mr. BOWERBANK's observations* on the blood of Insects stand alone, and deserve implicit confidence. "The blood (of insects), which is usually of a very transparent greenish or yellowish colour, is filled with a great number of little particles, which were described by CARUS as oblong or oval, but more correctly by Mr. BOWERBANK as flattened oat-shaped masses which retain their form while circulating through the body, but like the particles of blood in Vertebrata, become globular immediately they are brought into contact with water. It is stated by BURMEISTER that they vary in diameter from $\frac{1}{200}$ to $\frac{1}{260}$th of a line; but they differ also in size in the same individual, and are often rough and tuberculated, as noticed by EDWARDS, and as distinctly seen in the blood of *Sphinx ligustri*†." The preceding paragraph embraces the sum of our present knowledge on the histological character of the nutritive fluids of insects! It is impossible in the present limited communication to exhaust the materials comprised within a field of observation so vast and various. Among species so diverse and boundless the fluids must be characterized by corresponding varieties in physical characters. This is probable from the analogy derived from the examination of the fluids of the annulose series. It will accordingly be found, that although specific distinctions in the corpuscular elements of the fluids in the class "Insecta" are not unequivocally drawn as in the Annelida, under a marked typical unity for the whole class, specific diversities will notwithstanding be remarked to prevail. These varieties however are extremely obvious in the chylaqueous fluid of the larvæ of the several component species of the class.

Chylaqueous Fluid of the Larvæ of Insects.—At the first emergence of the larvæ of several species of insects from the ovum, no dorsal vessel is yet formed. The visceral space is filled with a fluid perfectly colourless, which fluctuates irregularly in the containing cavity and is charged with corpuscles, which vary histologically in different species. As every larva does not emerge out of the ovum in the same stage of development, the floating cells of the chylaqueous fluid will be found to present differences depending rather upon age than upon species. The accompanying illustrations, which are drawn with repeated and exact care, represent several examples of these floating cells as they occur in the principal species of water-larvæ, (figs. 44 to 51).

I have also noted with every practicable accuracy the characters of the bodies observed in the fluids of the larvæ of the Neuroptera, Hymenoptera, Lepidoptera and Coleoptera, with the uniform result of discovering that (until a very advanced period of the larval stage) they foreshadow in no one particular those which afterwards appear in the blood of the perfect insect. In the chylaqueous fluid of the larva of the Hay Moth (*Leptona candida*) they consist of oblong flat cells, exceeding in

* Entomological Magazine, vol. i. April 1833.

† Art. Insecta, by Mr. NEWPORT, TODD's Encyclopædia.

size those of the blood-proper of the same insect; each cell is thinly charged with molecules, but destitute of nucleus. These cells are not accidental productions; they are constant in every specimen. They belong physiologically to the embryonic stage of the circulating fluid, as the other (fig. 44) and more complexly-structured corpuscles pertain to the mature blood. They exhibit not the slightest trace of colour. In another instance of a water-larva they discovered themselves under a kidney-shaped figure (fig. 49), bearing no analogy to any variety discoverable in the fluids of any species of adult insect.

The corpuscles of the chylaqueous fluid of the larvæ of the Libellulidæ constitute minute, fusiform, transparent, pellucid bodies (fig. 48), abounding in great comparative number in the sustaining fluid; they present no nuclear cell, neither do they contain granules, two structural characters in which they differ strikingly from those of the blood of the perfect insect of the same species. In the instance of another water-larva, the fluid under consideration was found thickly charged with small discoidal bodies, minutely granulated (fig. 51). Many other varieties might be added, but enough data have been adduced to sustain the statement that the fluids of the larvæ of insects are characterized by morphous elements which contrast unquestionably with those of the blood of adult insects. These, then, are the grounds on which it is contended that the embryonic fluids of the Insect constitute a true chylaqueous system; that it is less complex than the true-blood by which it is destined to be succeeded; that its morphous elements are provisional; that its basis and bulk consist of water, vitalized by passage through the parietes of the digestive system; that, morphologically, its floating cells bear some relation to the species, but none to those of the true-blood by which they are to be followed; and that, finally, it is aërated before the evolution and independently of the agency of the tracheal system. The principal trunks of the tracheæ are distinctly visible in the body of the larva long before the *stigmata* (by which a communication is established between these tubes and the external medium) are formed. The air-tubes, however, while yet closed at both extremities, become filled with a gaseous substance. How is this curious fact to be explained? In the atmospheric larvæ they cannot derive their gaseous contents directly from the external air, for fluids and solids intervene; nor in the water-larvæ can they absorb the air of the surrounding medium, for they are situated too deeply in the interior of the body, those few species excepted in which appropriate appendages are provided for the exposure of the tracheal system. The inference is thus rendered probable that the tracheæ of the larvæ of Insects, whether their habitat be atmospheric or aquatic, become first filled with gas *from the fluid* occupying the visceral cavity—not because they already perform the office of aërating that fluid, but because their parietes are endowed with the peculiar faculty of absorbing gaseous elements *from fluids* by which they may be surrounded. Distended with gas, in the larva stage they subserve the mechanical office of suspending the aquatic species in their temporary habitation. The conclusion finally presses upon the mind, then, that the

first nutritive embryonic fluid of the Insect undergoes respiration on the *aquatic*, not on the atmospheric plan, conforming in this fundamental particular to the law governing the function in all chylaqueous fluids.

Blood-proper of Insects.—As already stated, Mr. BOWERBANK was the first to describe with exactitude the morphous solids of the blood of insects. But unfortunately for science his observations were instituted only on one species. No physiologist has yet rightly estimated the importance attaching to the history of the fluids in the animal series—not the cavities and channels and vessels in which they move, but the fluids themselves, histologically, morphologically, chemically, teleologically, as component elements of the living organism. *No zoologist is yet prepared for the assertion, that throughout the true articulated series there prevails but one fundamental type of blood-corpuscle.* The variations from this essential unity, coinciding with differences of class, order, genus or species, are never so deeply inscribed as to involve a departure from this type. It begins at the adult insect, and is unequivocally traceable through the intermediate forms of the Entomostraca, Crustacea, and Cirrhipeda, ending at the Arachnida. Here is a novel and unexpected confirmation of those affinities which are founded upon the resemblance of the solid parts. In the character of the fluids, the classifier is henceforth furnished with a new and important means of determining zoological differences and resemblances.

The blood of the perfect insect is colourless, and charged with colourless floating cells. It is impelled in a definitive orbit by a special power,—a dorsal vessel. Throughout the whole class its morphous elements consist of cells of peculiar construction. There is a conspicuous nucleus in each cell. It is surrounded by minute, pellucid, very slightly refracting granules. On bursting, these corpuscles *fibrillate.* It is not possible to detect separately the cell-capsule; though, from the constant and definite figure of the bodies, it admits of no dispute that a distinct involucrum exists. The figure varies from the orbicular to the oval or oat-shaped. They are flattened ovals, not *cubically* oval. They are almost immediately destroyed by water. The first phase is the pellucid molecule; the second an orbicular granular particle; the third the flattened oat-shaped cell. In every species of insect yet examined, the extremes of variations in form are bounded on one side by the orbicular, on the other by the fusiform. The fundamental form is the compressed oat-shaped. The illustrations (figs. 40 to 43) exhibit with strict fidelity the structural characters of these bodies. They are amplified 420 diameters.

Crustacea.—The fluids of the Entomostraca are supplied with corpuscles which fall under the articulate type already indicated. They are, however, more generally circular (figs. 52 to 55), always bearing a nucleus more or less discernible, and filled with minute granules. In *Branchipus, Daphnia* and *Cyclops,* they answer with exactness to the preceding description. They are not numerous relatively to the bulk of the fluid. In these little crustaceans, in the adult state, the circulating system is quite as simply constituted as that of insects. The dorsal vessel is the moving power;

the periphery of the system is lacunose. The history of the evolution of the fluids of these microscopic animals is yet to be known. The illustrations delineate faithfully the blood-corpuscles of *Daphnia, Cyclops,* and *Branchipus.* Magnified 420 diameters.

The fluids of the lowest crustaceans present all the essential features of the chylaqueous system. The *Picnogonidæ* afford the best examples. In these inferior genera, the digestive cæca float in the general cavity of the body. The space which intervenes between them and the integumentary exterior is filled with a colourless corpusculated fluid. The oscillations of this fluid are irregular, excited and sustained by the constant action of the arms and the undulations of the alimentary cæca. The corpuscles of this fluid are, relatively to its volume and to the size of the animal, very large. They depart as much from the normal articulate type as those of the embryonic fluid of the Insect do from those of the blood of the perfect animal. The inferior structural character of these bodies becomes expressive of a corresponding simplicity in the composition of the fluid. The walls of the cavity lodging the nutritive fluid in the *Pycnodon* are *not* ciliated. The corpuscles are spherical bodies, having an obvious cell-capsule, molecules, but no nucleus. *This,* like all other true chylaqueous fluids, is aërated at every part of its course throughout the body. Hence the absence of that which the simple nature of the fluid does not require, a special apparatus for respiration.

Nothing is yet known of the morphological characters of the nutritive fluids in the embryo condition of the higher Crustacea. The fluids also of the adult animals, though easy of investigation, remain almost wholly undescribed. Mr. WHARTON JONES, in his memoir in the Philosophical Transactions*, alludes only to the instances of the Lobster and the Crab; on comparison, however, it will be seen that between his delineations and mine there are wide differences.

In *Caprella linearis* (*Lœmodipodes,* CUV.), it is an easy process to observe the blood-cells circulating in the branchial appendages depending from the inferior surface of the body. They occur under three discernible varieties:—1st, simple, non-granular, non-nucleated, pellucid, spherical globules (fig. 56); 2nd, more or less orbicular bodies, of which the bright nucleus is prominent visible, and a mass of slightly refractive molecules; 3rd, the fact, characteristic of all blood-cells falling under the denomination of the articulate type, of the apparent suppression of the cell-capsule. In this species the blood-corpuscles are large relatively to the proportions of the body. On bursting in the field their contents *fibrillate* in a very obvious manner. In every observation I have been attentive to note this interesting fact; it may avail some future theorist.

The blood of the *Amphipodæ* is distinguished for the prevailing orbicular character of its floating cells. The elliptical figure seldom occurs. The nucleus is more centrally situated, and therefore less visible than is common among the Crustacea. The

* *Op. cit.*

absence of the cell-capsule is readily observed. In dimensions these bodies are proportionately small. Those of *Talitrus locusta* and *Gammarus pulex* are characteristic examples (fig. 57).

In the *Paguridæ*, or Hermit-crab family, the blood-corpuscles are prevalently ovoidal; instances, however, of the elliptical and spherical figures are remarked among them. In every typical character they coincide with the articulate model,—the nucleus prominent, and generally placed eccentrically. The corpuscles are granular and the involucrum apparently wanting. They fibrillate when rupturing in the most striking manner. Those of *Pagurus Bernhardii* (fig. 58) will serve to exemplify this class. The blood of the Brachyourous Decapods is distinguished for its comparatively large and prevailingly spherical corpuscles. In all the pellucid nucleus is a prominent object; it is always near some point of the circumference. The granules are so large as to be readily individualized by the eye. The involucrum is so attenuated, if existent at all, as not to be appreciable. As in the blood of all other crustaceans, three grades of development may in this instance be recognised:—1st, the pellucid, nucleus-less globule; 2nd, the nucleated cell, with a few surrounding molecules; and 3rdly, the mature cell, in this case approaching the sphere in figure. The fibrillation of the cells is here too invariably remarked. In consequence of the legible size of the objects, it is possible *to prove*, with reference to the blood-corpuscles of the Crab, that the fibrillation observed during the rupture of the cell, arises from the coagulation of the cohesive liquid by which the *molecules* (not the nucleus), constituting the great bulk of the corpuscle, are filled. It is probable, therefore, that *each molecule* is a miniature factory for fibrine. The nutritious fluid of the Macrourous Decapods is little different morphologically from those already described. The corpuscles, however, are more generally elongated, so that the oat-shaped constitutes the average form; in all other respects they conform intimately with those of other Crustacea. Those of the Lobster, Cray-fish, Prawn, and Shrimp (figs. 59, 60, 61), will serve to illustrate the characters of the solid elements of the blood in this order of Crustaceans. It will be observed that they present, severally, slight variations of size and form, which coincide with the differences of species. But through them all there runs a continuous evidence of an essential unity of type.

Arachnida.—The naturalist is scarcely prepared for the announcement that the morphous elements of the blood of the Arachnid constitute the terminal link in the fluid-chain of the Articulata. In all the spiders of this country the corpuscles of the blood occur under the character of minutely granular bodies, varying between the spindle-shaped and orbicular in figure. Though absolutely small, they are, relatively to the size of the body of the animal, as large as those of the Crustacean. They differ from those of the latter in the position and invisibility of the nucleus. It is seated in the geometrical centre of the body, and therefore indetectable, because surrounded by molecules which are the exact counterpart of those formerly described in the blood-cells of the Crustacea. Like those of the latter cells, the molecules of the blood-

corpuscles of the Arachnid are capable only in a very slight degree of refracting light; hence the peculiarly translucent and delicate character of these bodies. In a perfectly fresh state, and unmixed with any menstruum, they are readily defined. The cell-capsule is as undetectable as it is in the Crustacea. In *Arachna grandis*, and the common House Spider, illustrative examples may be easily obtained (Plate XXXIV. fig. 62 and 63).

The conformity of the Arachnid blood-corpuscle to the normal articulate type is placed by these examples beyond doubt. Thus is presented to the philosophic zoologist a new and unexpected order of affinities as valuable as those established through observed resemblances in the systems of the solid organs, and by which in future every scheme of classification must be either corrected or confirmed. The physiologist will now recognise in the mysterious unity of form and structure which pervades even a microscopic cell, floating detachedly in a fluid, an immutable law of organic continuity through which the thoughtful eye may trace relationships between animals far separated in the zoological series.

Mollusca.—Cuvier, Owen, M.-Edwards, and recently, and more minutely, Alder and Hancock, have, by their several researches, elucidated with great success the mechanism of the circulation in the Mollusca. To this department of the subject of this memoir, it is not in my power, at present, to make any considerable addition. It is remarkable, that, while studying the *channels* of the fluids, the great observers named did not on any occasion digress to an examination of the fluids themselves*.

In addition to the historical sketch formerly presented, it must here be stated that the most recent essay on the blood of Mollusks is that which has lately appeared from the pen of M. Moquin-Sandon†. This writer devotes some pages of his short paper to a discussion of the point whether the red viscid fluid which appears to escape from the edges of the mantle of the Planorbidæ when irritated, is blood or not blood. Having exhausted the controversy, he concludes that it is blood. "Examinée au microscope," he observes, "au moment où elle sort de l'animal, on y remarque un certain nombre de corpuscles irrégulièrement arrondis, inégaux, tout à fait semblables aux globules sanguins des Gastéropodes. Leur diamètre est de $\frac{1}{100}$, $\frac{1}{75}$ et $\frac{1}{50}$ de millimètre." It will be afterwards shown that the following propositions of Moquin-Sandon are contradicted by the best observed facts. "1. Les Planorbes ont le sang rouge ou rougeâtre; 2. Les très petites espèces ont le sang rose ou couleur de chair; 3. La liqueur répandue par ces Mollusques, quand on les irrite, n'est pas une humeur particulière sécrété par le collier, ni par tout autre organe, mais du sang mêlé à la mucosité; 4. Le sang, épanché dans la grande cavité du corps des Planorbes, comme chez les autres Gastéropodes, se voit distinctement, pendant la vie, quand il est très rouge, chez les espèces à coquille transparente; 5. Le sang répandu par les Planorbes, quand l'animal se retire brusquement et profondément dans sa coquille, n'est pas

* See *ante*.

† Mémoires de l'Académie de Toulouse, 1849; and afterwards copied into the Ann. des Sc. Nat. 1851.

exprimé, par la marge du manteau, mais il sort de l'étroit espace située entre cette marge et la coquille; 6. Dans une contraction extrême, le sang peut exuder par toutes les parties du corps." From the language of these propositional corollaries, it is certain that M. MOQUIN-SANDON scarcely knows what is, or what is not the *blood* of the Planorbidæ. Such uncertainty illustrates the sources of those numerous errors which render the historical literature of this subject really of little value. It is of the highest importance to the progress of knowledge that the *same fluid* should be examined by all the observers engaged in the same pursuit. Independent observations *under such circumstances* become conducive to the development of truth*.

In the Mollusk there is but one system of fluids. It unites in itself the separate characteristics of the blood-proper system and the chylaqueous. In the mechanical character of the circulating system this union of opposite qualities is discernible. In the histology of the fluids it is still more so. In the transition through the Molluscan route, between the Annelida and the Vertebrata, the blood of the Mollusks exhibits the mean of these two extreme constituents. Unlike the blood of the Annelid, it is the seat of floating corpuscles, and different from that of the animal; these corpuscles are not organized with regularity of plan. They exhibit more constancy of structure than the morphous elements of the chylaqueous fluid, less so than those of the blood of the vertebrated animal. The blood of the Mollusk is indeed in every physiological property intermediate between that of the vertebrate animal and the chylaqueous fluid of the Annelid. If perhaps the blood-proper of the Annelid were mixed with the chylaqueous fluid, the product would represent the Molluscan blood. Why in the one case these constituents should be held permanently separated, and in the other blended into one fluid, it is not easy to explain.

In the Molluscan scale a considerable interval separates the tunicated orders from the Cephalopod. This interval of separation, so marked in the solids, is scarcely recognisable in the fluids. The blood-corpuscle of the Myriapod is far less distinguishable from that of the Arachnid than the Scolopendra is from the Spider. To the former case this is an illustrative parallel; so much more intimate is the affinity which pervades the fluids, than that which links together the systems of the solid organs in the animal series.

* Preliminarily to the investigations related in the text, I am desirous in this place to state with clearness, the mode which I have adopted in procuring the fluid intended for examination in the Mollusca; a class in which it is far more difficult to *isolate* the nutritious fluids than in any other. In every instance an eye conversant with these especial objects is required. The cells of the solid structures, when loosely floating in a fluid, may easily deceive an inexperienced observer. The blood-corpuscles in every species should first be unquestionably identified, by *seeing them* moving IN the blood-channels. When, in the larger species, the heart is a conspicuous body and admits of ready separation from all surrounding structures, the blood may be drawn directly from this source. In many of the DRY land species, as the Helix family, it suffices to lay open the mantle and expose the *areolæ* of the visceral cavity. The fluid escaping under such circumstances is true-blood. The smaller Mollusca must, however, with *infinite* patience, be submitted to microscopic examination; the observer must stedfastly gaze until the soft parts are protruded beyond the limits of the shell, which in nearly all cases is too obscure and impenetrable to light to enable the eye to read the included living fluids.

In every Mollusk* yet examined the blood has been found to be colourless, not colourless like distilled water, but like very dilute milk. It is more *coagulable* than any variety of chylaqueous fluid; and from its viscidity it is undoubtedly more highly charged with the fibrinous principle than the latter. This fact results necessarily from the circumstance, that it constitutes in itself the entire fluid element of nutrition in the Mollusks, and that it is the seat of direct corpuscular agency. In this series the blood is invariably corpusculated. The proportion of the floating cells to the fluid varies however in different orders. In the Bryozoa and Tunicata, these bodies are relatively scanty. In the Cephalopods they are very numerous. Hereafter, in the progress of physiology, the law will be established, which recognises a *vital proportion* between the *measure of corpusculation*, presented by the fluids and the 'place' of an animal in the series. One unaided observer cannot adventure upon a generalization which should have for its basis a multitude of "facts." It is a remarkable *law*, which has now been demonstrated to preside over the blood of the articulate *and* the molluscan series, that in scarcely a single instance is it the seat of colour. In all cases except that of the Annelida the pigment is developed only in the cells of the solid structures. Among vertebrated animals, colour, *and only the red colour*, prevails without exception. Why should the blood-proper of the Annelids constitute an exception to a rule which applies to *all other* classes within the wide bounds of the invertebrate subkingdom? These are queries pregnant with undelivered meaning.

The *Bryozoa*, the lowest of the Mollusks, possess no vestige of a true-blood system. Neither a heart nor vessels under any shape can be discovered in any species. The nutritive fluid occupies the visceral cavity. It is imperfectly corpusculated, and oscillates in its containing chamber under the agency of muscular contractions. The branchiæ are cæcal tubes into which the fluid of the general cavity of the body freely enters, and in which it moves in *flux and reflux currents*. As foreshadowing a character of constant occurrence in the circulating system of Mollusks, this peculiarity should be specially noted. It is a specializing of the system in *some part* of its periphery while others remain degraded. It has been of late shown by the beautiful researches of ALDER and HANCOCK, that in the Nudibranchiate Mollusks there are distinguishable three peripheral specializations, the portal, the branchial, and the renal. In these subsystems an approximation to a capillary reticulation of the conducting channels occurs. The branchial canals of the Bryozoa first typify the Molluscan law just defined. The morphous elements of the fluids in the Bryozoa, as formerly explained, admit of easy observation in *Laguncula repens*, in any of the *Flustræ*, *Lepraliæ* or *Escharæ*, most readily, however, in *Bowerbankia*. This consists of globules of various forms and size; some are only opake, milky spherules, without nucleus or granules; others are nucleated; and a third variety, comprising the adult form of the cell, discovers a nucleus, small and centrally placed, surrounded by granules, constituting an orbicular corpuscle.

* I speak of course within the bounds of my own personal observations.

Thus in a brief phrase is expressed a structural principle which governs the formation of the blood-corpuscle in all Mollusks.

The Bryozoa are to the Molluscan what the Pycnogonidæ are to the crustacean series. In the Bryozoa and Pycnogonidæ the vital fluids are constituted in the organism into *a system*, in strict accordance with the chylaqueous. How perfectly these two instances prove that nature, in cases of simple organisms, gathers together and circulates the nutritive fluids on the type and plan of *this* system, and not on *that* of the true-blood! This fact indicates in the former, with respect to the latter, a relation of inferiority. In both the instances enumerated, the fluids notwithstanding exhibit an advance upon the true chylaqueous fluid, in the fact that the corpuscles are more highly organized, while the fluid itself is more perfectly fibrinized, indications both of a higher degree of vitalization.

In the *Tunicata* the apparatus of the circulation is developed obviously above the standard of the former. A heart and arterial trunks are detectable. The blood currents, however, are not determinate in direction. As in the larva of insects, the portions of the fluid which accumulate in the peritoneal chambers oscillate to and fro under the muscular contortions of the body; presently, however, and at unequal intervals, it obeys the impelling force of the heart, and advances in a definite orbit. In the Cynthidæ or Salpidæ the fluids may be readily obtained for examination*.

It is colourless, and discovers very distinctly the property of coagulating. The solid elements (figs. 64 and 65), relatively to the bulk of the fluid, are scanty. Similarly to what was observed in the Bryozoa, the cells exhibit several varieties. It is a fact of considerable interest, that the floating cells of all inferiorly vitalized fluids should be characterized by *variety* more or less numerous, in the form, size and structure of the corpuscular elements. The adult type of the corpuscle in the blood of the tunicated Mollusk is marked by no other feature of constancy than that of the orbicular figure. Sometimes this form is modified into the flat circular; frequently the cells are simply nucleated, again they are destitute of this part. All those which may be reckoned as mature, contain, in addition to a nucleus, granules, forming more or less of the bulk of the cell. The cell-capsule is more evident in this class than in the former. If submitted to the action of an endosmotic medium, such as water, it fibrillates more obviously than the corpuscles of an unmixed chylaqueous fluid. This character is a mark of superior organization.

In the class of the *Lamellibranchiate* Mollusks, the readiest and surest method of observing the blood-corpuscles consists either in viewing them in motion directly in the branchial vessels, or in isolating the heart, placing it under the microscope and

* For this purpose, in these animals, the tunic and branchial chamber should be opened freely; the fluid occupying the cells of the space intervening between these two parts will be found to be true-blood, the corpuscles of which, if thus obtained, should be carefully compared with those in the same specimen *seen* moving in the branchial vessels.

distinguishing the corpusculated fluid as it escapes, under pressure, from the little cavity of the organ*.

Like that of all other Mollusks, the blood in this order is colourless, limpidly opalescent, and charged with corpuscles which present three main varieties:—1st, the round granular cell, which is probably the mature form of the blood-corpuscle; 2nd, a nucleated, orbicular, pellucid cell, destitute of all other contents; and, 3rd, minuter globules filled only with an opalescent fluid. In the Lamellibranchiate family, the blood is corpusculated on *one* plan. It is almost impossible to indicate structural differences between the blood-cells of *Pholas* (fig. 71) and those of *Pinna* (fig. 72), or between those of *Mya* (fig. 69) and those of *Solen* (fig. 70), or those of the Oyster (fig. 68) and those of the Mussel (fig. 69). The blood of the small fresh bivalves is less obviously corpusculated, and the corpuscles themselves are less impregnated with granules. Although exhibiting the limpidity of pure water, it coagulates into clots on escaping from the body. As yet a manifest *unity of plan* in the structure of the blood-corpuscles of the Mollusca has not been found to prevail in the classes examined. Nowhere has there existed *one invariable ever-present* form of corpuscles, such as obtains in the blood of the articulated animal, and varieties present themselves in every instance. But under this variety there runs a legible unity. The forms of cells, various though they be, which characterize the blood of the lower Mollusks now examined, are undoubtedly pervaded by a community of structural characters; through individual diversities there runs a chord of continuous union. The two remaining groups of Mollusks, the Gasteropods and Cephalopods, present signs of some advance upon the former in the vital composition of the fluids. Preserving the type of the molluscan blood-corpuscle, they lose some of the irregular, aberrant forms of the cells.

Gasteropoda.—The freshwater Gasteropods, in which the blood can be *seen* rolling in its containing channels, become serviceable as standards of comparisons for determining the true-blood corpuscle of other species of this family. The Planorbidæ are readily examined for the blood in the living state. The horns and foot are hollowed out in the interior, into spacious axial channels, into which the blood rushes under the compression of muscular force. This is the real mechanism by which the arms of the Brachiopods are extended. My observations on the blood of the Planorbidæ conduct me to conclusions at diametrical variance with those of MOQUIN-SANDON†. The true-blood of these Mollusks is colourless, not, as maintained by naturalists, red and purple. I demur to his method of observation. The mantle, when the animal is irritated, does throw out a coloured fluid, but that is not *the blood* of the animal. Ob-

* As to one unpractised in these delicate researches some difficulty may attend the method stated in the text, a *certain* view of the corpuscles of the blood may be obtained by placing a minute freshwater bivalve, such as a *Pisidium*, in a *cupped* glass under the microscope; when the soft parts, such as the siphons, edge of the mantle and foot, are being protruded beyond the limits of the shell, the movement of the blood, as it slowly distends these parts, can be very clearly and perfectly observed.

† Annales des Sciences Naturelles, 3me Série, 1851.

served carefully in an unmutilated specimen while yet living, the real blood may be seen rolling into the axes of the tentacles, a perfectly colourless, corpusculated fluid. No other mode of examination is exempt from fallacy. The corpuscles are spherical granular cells, furnished with a nucleus, which, from its central situation, is commonly indetectable. The elliptical and oat-shaped forms are never seen; other immature cells may be observed, but the real blood-corpuscle of *Planorbis corneus* (figs. 78 and 79) is a round granular cell of extreme delicacy, colourless and pellucid.

In the Helix and Limax families, from the large size of the specimens, and from the conspicuous milk-white colour of the blood-vessels, no difficulty obstructs the process of observing the blood. It is not much to be wondered at that every anatomist during the last half-century, from CUVIER to QUATREFAGES, have erroneously supposed the *blood* to be of a milk-white colour, because the *vessels* are so. The *coats* of the vessels are pure white, like milk; but the blood itself is almost colourless. The vessels derive their colour from the presence of a layer of *adipose tissue in their coats.* Why this excentric structure should exist it is not easy to explain; but *it is* so. The readiness with which the fat-cells escape from their areolæ, renders the separate observation of the blood-corpuscles very difficult. The real blood-corpuscles are quite different from the fat-cells; they are spherical granular bodies. They bear an obvious analogy to those of the lower molluscan groups, and yet they are different. They appear to consist of *firmer* substance. The molecules filling the interval between the nucleus and the involucrum refract the light more abruptly. They are mingled in almost equal proportion with minute oval cells destitute of nucleus and without granules (figs. 76 and 77). The spacious areolæ which surround the intestinal canal are filled with true blood. When the tegumentary mantle is opened it escapes in considerable volume. It determines the real character of the blood in this highly organized family of Gasteropods. It *does not* partake of the milky colour of the arteries, as stated by CUVIER. It is pellucid, a little less so than distilled water. It possesses, in the highest degree, the property of coagulating. In this respect it strikingly differs from the chylaqueous fluid of the Annelida, which was remarked to be gifted in a *minimum degree* with the clot-forming faculty. Physiology will hereafter inevitably prove, that between the coagulating property and the structure and number of the floating cells, there exists a relation of proportion which is yet unresolved. The blood-corpuscles of the Whelk and Limpet (figs. 73, 74, 75) fall under the description now given. The *Cephalopods* constitute the climax of the molluscan series: this observation is alike true of the solids and the fluids. Like that of other Mollusks, bluish and colourless, the blood of the Cephalopods is rich in floating cells; of more determinate and elaborate formation, however, than those of other Mollusks. They present far more striking uniformity in size and form than anything observed among the inferior molluscan families. In this fact they exhibit a near approximation to the vertebrate type of blood-corpuscle. These are signs of superior organization. They are provided always with a nucleus, situated for the

most part centrally, but sometimes peripherally. The space between the nucleus and involucrum is filled with a light bluish fluid, thickly impregnated with point-like molecules, and here and there a larger oil-cell. Another variety of cell, wholly destitute of contents, may be remarked (fig. 80); these latter are probably the germ state of the former. Between these intermediate forms may be observed. The mature cells preserve a striking regularity of size and structure; they are invariably capsulated, but this capsule is very thin.

Multiplied observations will enable a future generaliser to establish, for the configuration and structure of the blood-corpuscles of the several leading orders of Mollusks respectively, a *certain* and definitive law. The blood-cells of the Bryozoa will have their generic characters, those of the Tunicata theirs, and the Conchifera, the Gasteropoda, Pteropoda and Cephalopoda severally theirs.

Between them all there will be found some feature in common. The real law which presides over the conformation and structure of the corpuscular elements of the living fluids remains yet to be discovered. In what possible manner a mere modification of *figure* can influence the agency of these free cells, the physiologist at present cannot conjecture. But why should greater mystery attach to the shape of a blood-corpuscle than to that of the body of the animal itself? The zoophytic, medusan, echinodermal, articulate and molluscan blood-corpuscles are only correlates severally of the varied organisms which belong to the links enumerated of the invertebrate series. Though destitute of colour, the floating cells of the Cephalopods resemble most nearly those of the blood of the Vertebrata. Thus, I trust, has been shown in the fluids as well as in the solids of the organisms constituting the zoological series, a vital and structural graduation. To the future progress of physiological science the clear apprehension of this truth is most important.

Recapitulatory statement.—I have now, I trust, shown by the force of a large mass of evidence, that the circulating fluids in the *Invertebrata* occur under *three distinct classes*, distinguished from each other by prominent and unquestionable differential characteristics; that the lower and lower we descend in the invertebrate scale, the less and less organized, the more and more *like* lifeless salt water the nutrient fluids become; that the fluids (especially their solid elements) of the body in degrees of organization progress *pari passu* with the solids; that classified on the basis of the evidence afforded by the *fluids*, the *articulated series really begins at the Echinodermata*, and ends with the *Arachnida*, for throughout this series an uninterrupted line of *continuous* affinities may be clearly and indubitably traced. In every class *in this series, either temporarily* or *permanently, two fluids* are provided for the nutrition of the organism. As the *Rotifera*, judged by this rule, have only a single system of nutrient fluids like the Mollusca, it is evident that they cannot form a link in this beautiful chain; without them it is continuous, with them it is broken. The molluscan chain diverges from the former *at* the *Acalephæ*: it is traceable *uninterruptedly* to the highest Cephalopod. In all the classes of which this subkingdom is constituted

there exists but ONE system of fluids, appearing as if the central stomach of the Acaleph had been suddenly *partitioned* from its dependent cæcal prolongations. Viewed from the novel vantage point afforded by the fluids, the mind is led to contemplate the whole invertebrate kingdom under the guidance of three leading ideas:—1st. It sees in the Zoophytes a group of animals in which the fluids form a *single system in free communication with the external element.* Advancing to the limit of the Echinoderm, it suddenly descries the superaddition of a totally distinct system, that, namely, of the true-blood, *while the former still persists*; it tracks this double fluid-chain up to the highest articulated animal; and, 3rdly, at the highest frontier line, bounding the Medusæ, it observes a divarication in the chain, by the divergence from the originally *single* portion of the molluscan branch. In the *Mollusca*, like the *Protozoa*, the fluids constitute a single system; but the system of the circulating fluids in the former is distinguished from that in the latter by this important fact, that between it and the external element there exists no *direct* communication as in the *Protozoa*. In the Protozoa the nutrient fluids are chylaqueous, in the Mollusca they are *true-blood*, moving in a *closed circle*, *not of cylindrical vessels*, however, and excluded from all direct relation with the surrounding element; that is, before salt water, in this class, is admitted into the blood, it must, by the laws of this system, have first received an *incipient* organization, by passage through the stomach. The assimilating power of the chylaqueous fluid, therefore, as it exists in the Protozoa and Echinoderms and Annelida, when exerted upon salt water, immediately converts the latter into a *vital* organized fluid. This power is not possessed by true-blood. Classified in accordance with the principles established by the foregoing history of the comparative anatomy of the fluid elements of nutrition, the diagram here presented (Plate XXXV.) would illustrate the arrangement of the invertebrated classes.

Swansea, December 12, 1851.

EXPLANATION OF PLATES.

All the following illustrations were examined under and drawn by a one-fourth and a one-eighth power of one of POWELL and LEALAND's best microscopes.

PLATE XXXI.

Fig. 1. Corpuscles floating in the chylaqueous fluid of *Tubularia indivisa*. Magnified 320 diameters.

Fig. 2. Corpuscles floating in the chylaqueous fluid of *Bowerbankia denea*. Magnified 320 diameters.

Fig. 3. Corpuscles floating in the chylaqueous fluid of the gastro-vascular canals of *Rhizostoma*. Magnified 300 diameters.

Fig. 4. Corpuscles floating in the chylaqueous fluid of *Sipunculus Harveii*. Magnified 300 diameters.

Fig. 5. Corpuscles floating in the true-blood of the same *Sipunculus*. Magnified 320 diameters.

Fig. 6. Corpuscles floating in the chylaqueous fluid of *Sipunculus Johnstoni*. Magnified 300 diameters.

Fig. 7. Corpuscles floating in the true-blood of the same Sipuncle. Magnified 320 diameters.

Fig. 8. Corpuscles of the chylaqueous fluid of *Uraster rubens*. Magnified 300 diameters.

"Those in the fluid of the 'feet' are *identical*; those in the true-blood are also identical with those figured."

Fig. 9. Corpuscles of the chylaqueous fluid of *Solaster papposa*.

Fig. 10. Corpuscles of the chylaqueous fluid of *Cribella ocellata*.

Fig. 11. Corpuscles of the chylaqueous fluid of *Echinus sphæra*. Magnified 300 diameters.

Fig. 12. Corpuscles of the chylaqueous fluid of *Ophiocoma rosula*. Magnified 320 diameters.

Fig. 13. Corpuscles of the chylaqueous fluid *in* the alimentary organ of the Entozoon of the Hake. Magnified 320 diameters.

Fig. 14. Those of the chylaqueous fluid of *Arenicola piscatorum*. Magnified 320 diameters.

Fig. 15. Crystals of chloride of sodium obtained by evaporating the same.

Fig. 16. Corpuscles of the chylaqueous fluid of *Nais filiformis*. Magnified 400 diameters.

Fig. 17. Corpuscles of the chylaqueous fluid of *Sabella vesiculosa*. Magnified 300 diameters.

Fig. 18. Corpuscles of the chylaqueous fluid of a young *Nais filiformis*.

Fig. 19. Corpuscles of the chylaqueous fluid of *Sabella à sang vert*. Magnified 320 diameters.

Fig. 20. Corpuscles of the chylaqueous fluid of *Terebella nebulosa*. Magnified 400 diameters.

PLATES XXXII. and XXXIII.

Fig. 21. Corpuscles of the chylaqueous fluid of *Terebella conchilegia*. Magnified 320 diameters.

Fig. 22. Corpuscles of the chylaqueous fluid of *Lumbricus terrestris*. Magnified 300 diameters.

Fig. 23. Corpuscles of the chylaqueous fluid of a young *Lumbricus*.

Fig. 24. Corpuscles of the chylaqueous fluid of *Œnone maculata.* Magnified 300 diameters.

Fig. 25. Corpuscles of the chylaqueous fluid of *Borlasia*? contained *in* the alimentary organ. Magnified 300 diameters.

Fig. 26. Corpuscles of the chylaqueous fluid of *Phyllode lamelligera* (in visceral cavity). Magnified 320 diameters.

Fig. 27. Corpuscles of the chylaqueous fluid of *Nereis margaritacea.* Magnified 400 diameters.

Fig. 28. Corpuscles of the chylaqueous fluid of *Spio coniocephala.* Magnified 320 diameters.

Fig. 29. Corpuscles of the chylaqueous fluid of *Myrianida*?. Magnified 320 diameters.

Fig. 30. Corpuscles of the chylaqueous fluid of *Nais maculosa.* Magnified 320 diameters.

Fig. 31. Corpuscles (red) of the chylaqueous fluid of *Glycera alba.* Magnified 400 diameters.

Fig. 32. Corpuscles of the chylaqueous fluid of *Nais*?. Magnified 320 diameters.

Fig. 33. Corpuscles (red) of the chylaqueous fluid of *Clymenoida arenicoida.* Magnified 320 diameters.

Fig. 34. Corpuscles of the chylaqueous fluid of *Sigalion boa.* Magnified 400 diameters.

Fig. 35. Corpuscles of the chylaqueous fluid of *Matuta*? (Williams). Magnified 300 diameters.

Fig. 36. Corpuscles of the chylaqueous fluid of *Aphrodita aculeata.* Magnified 300 diameters.

Fig. 37. Corpuscles of the chylaqueous fluid of young *Arenicola.* Magnified 320 diameters.

Fig. 38. Corpuscles of the true-blood of *Iulus.* Magnified 320 diameters.

Fig. 39. Corpuscles of the true-blood of *Scolopendra.* Magnified 320 diameters.

Figs. 40, 41, 42, 43. Severally examples of the corpuscles of the true-blood of Insects. Magnified 320 diameters.

Figs. 44, 45, 46, 47, 48, 49, 50, 51. Examples of the corpuscles of the chylaqueous fluid of the larvæ of Insects.

Fig. 52. *Entomostraca.*—Corpuscles of the true-blood of *Moina branchiata.* Magnified 320 diameters.

Fig. 53. Corpuscles of the true-blood of *Daphnia pulex.* Magnified 320 diameters.

Fig. 54. Corpuscles of the true-blood of *Apus cancriformis.* Magnified 320 diameters.

Fig. 55. Corpuscles of the true-blood of *Cyclops quadriformis.* Magnified 320 diameters.

Fig. 56. Corpuscles of the true-blood of *Caprella linearis.* Magnified 300 diameters.

Fig. 57. Corpuscles of the true-blood of *Talitrus saltator.* Magnified 300 diameters

Fig. 58. Corpuscles of the true-blood of *Pagurus Bernhardii.* Magnified 300 diameters.

Fig. 59. Corpuscles of the true-blood of the Cray-fish. Magnified 300 diameters.

Fig. 60. Corpuscles of the true-blood of the Lobster. Magnified 420 diameters.

PLATE XXXIV.

Fig. 61. Corpuscles of the true-blood of the Crab. Magnified 420 diameters.

Fig. 62. Corpuscles of the true-blood of *Arachna grandis.* Magnified 320 diameters.

Fig. 63. Corpuscles of the true-blood of the House Spider. Magnified 320 diameters.

Fig. 64. Corpuscles of the true-blood of *Cynthia morus.* Magnified 300 diameters.

Fig. 65. Corpuscles of the true-blood of *Salpa maxima.* Magnified 300 diameters.

Fig. 66. Corpuscles of the true-blood of *Pisidium.* Magnified 300 diameters.

Fig. 67. Corpuscles of the true-blood of *Mytilus edulis.* Magnified 300 diameters.

Fig. 68. Corpuscles of the true-blood of *Ostrea edulis.* Magnified 300 diameters.

Fig. 69. Corpuscles of the true-blood of *Mya.* Magnified 300 diameters.

Fig. 70. Corpuscles of the true-blood of *Solen.* Magnified 300 diameters.

Fig. 71. Corpuscles of the true-blood of *Pholas.* Magnified 300 diameters.

Fig. 72. Corpuscles of the true-blood of *Pinna.* Magnified 300 diameters.

Fig. 73. Corpuscles of the true-blood of *Buccinum.* Magnified 300 diameters.

Fig. 74. Corpuscles of the true-blood of *Patella.* Magnified 300 diameters.

Fig. 75. Corpuscles of the true-blood of *Patella* ?. Magnified 300 diameters.

Fig. 76. Corpuscles of the true-blood of *Limax.* Magnified 300 diameters.

Fig. 77. Corpuscles of the true-blood of *Helix.* Magnified 300 diameters.

Fig. 78. Corpuscles of the true-blood of *Planorbis.* Magnified 300 diameters.

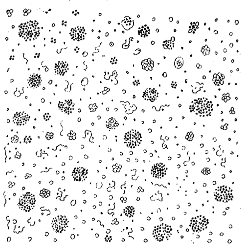
Fig. 79. Corpuscles of the true-blood of *Planorbis.* Magnified 300 diameters.

Fig. 80. Corpuscles of the true-blood of *Octopus vulgaris.* Magnified 300 diameters.

PLATE XXXV.

Diagram illustrative of the Classification of the Invertebrated Animals on the basis of the Fluids.

Fig. 1.



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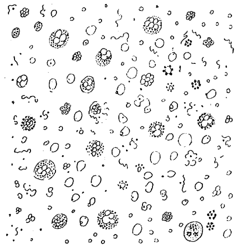

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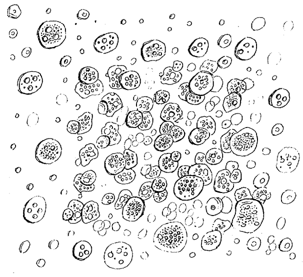

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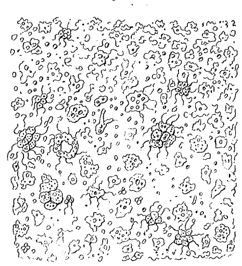

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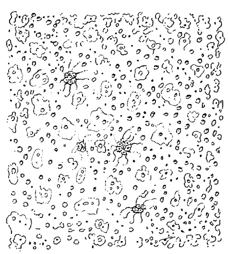

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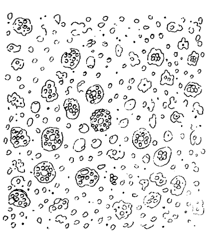

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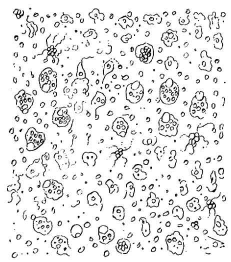

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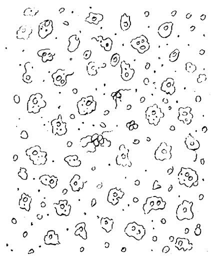

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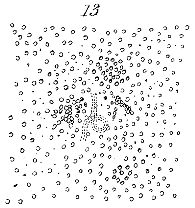

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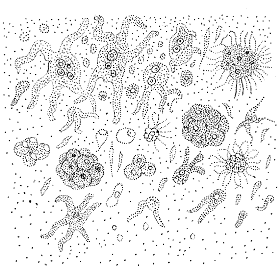

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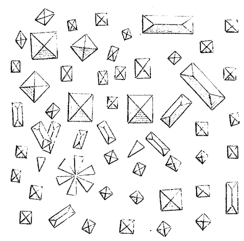

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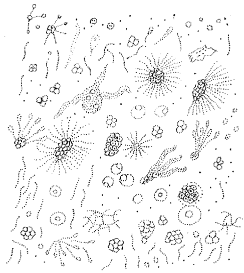

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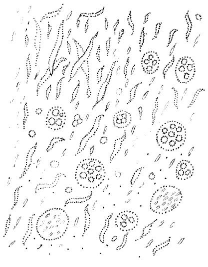

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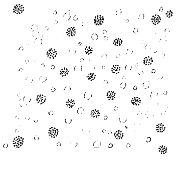

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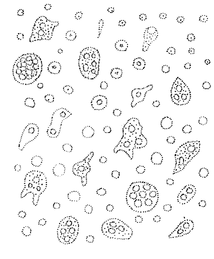

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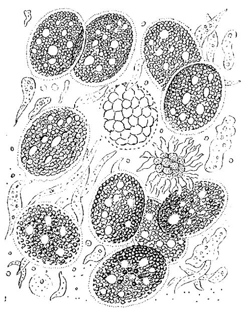

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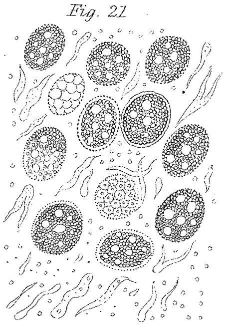
Fig. 21



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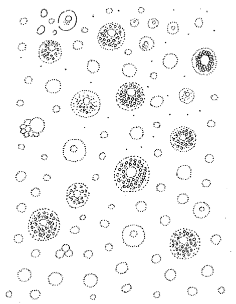

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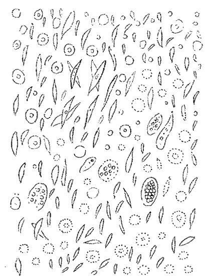

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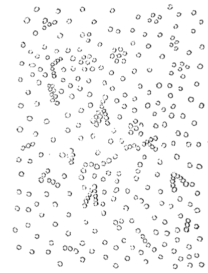

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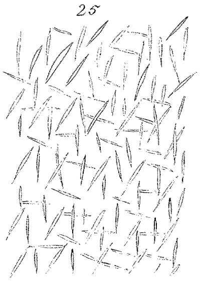

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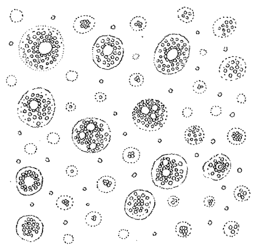

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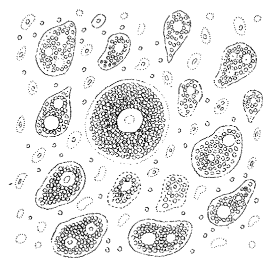

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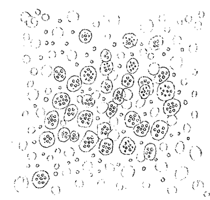

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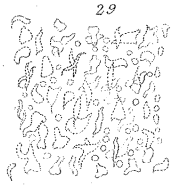

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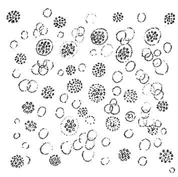

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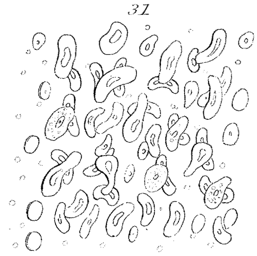

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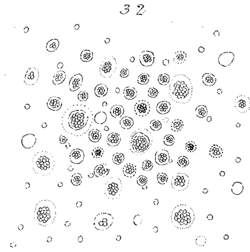

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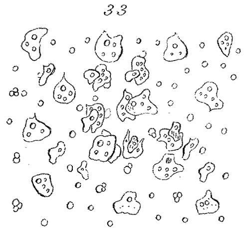

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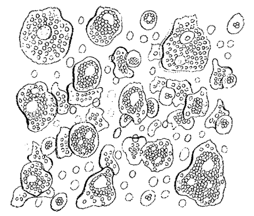

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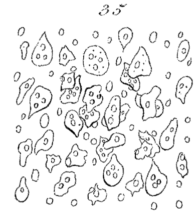

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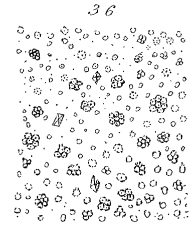

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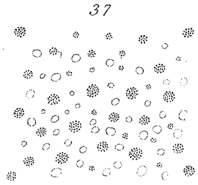

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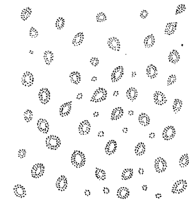

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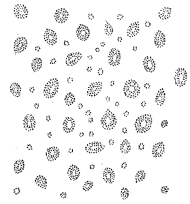

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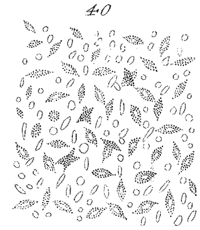

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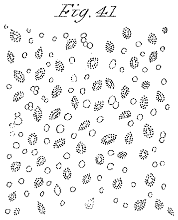
Fig. 41


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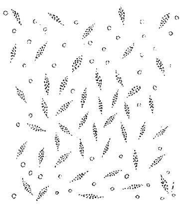

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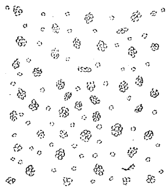

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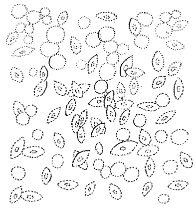

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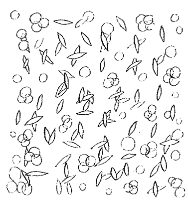

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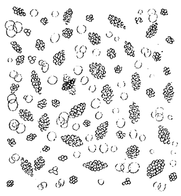

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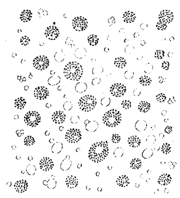

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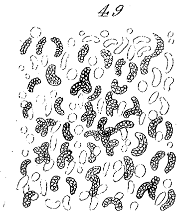

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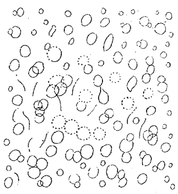

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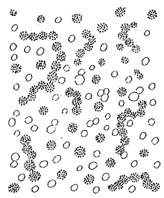

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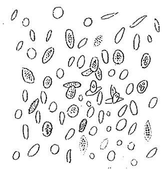

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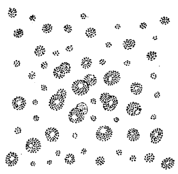

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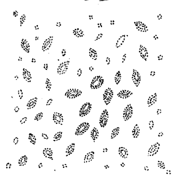

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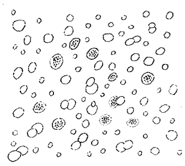

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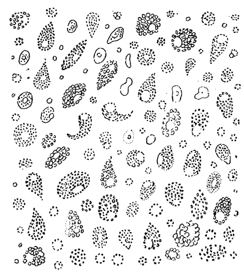

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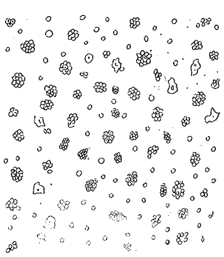

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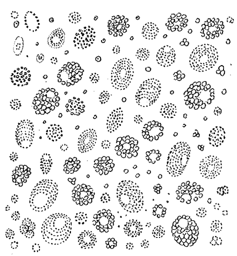

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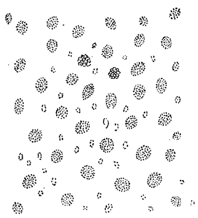

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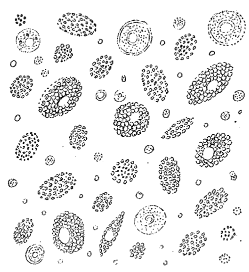

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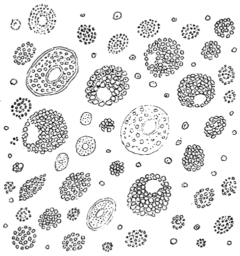
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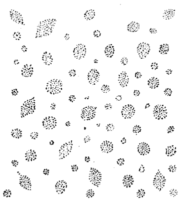
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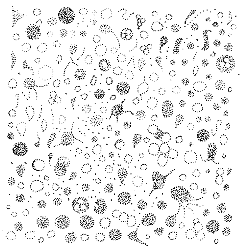
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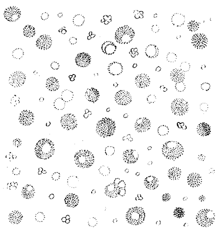
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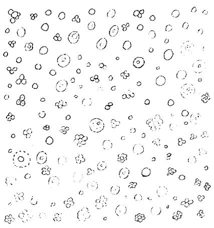
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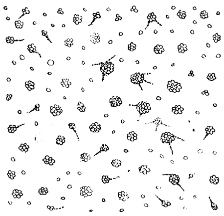
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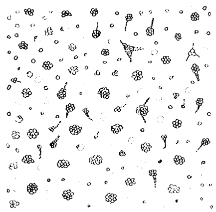
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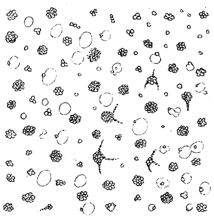
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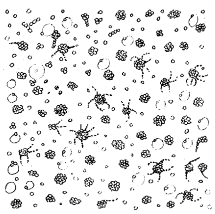
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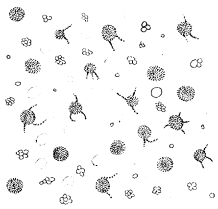
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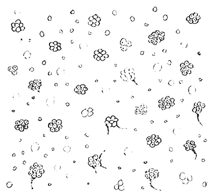
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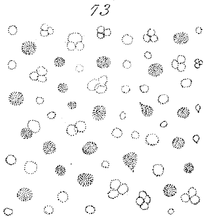
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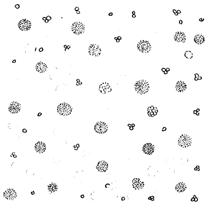
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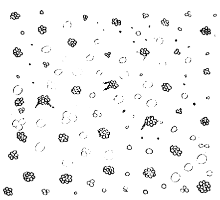
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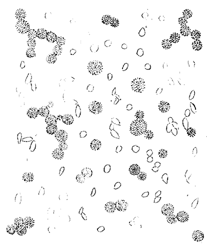
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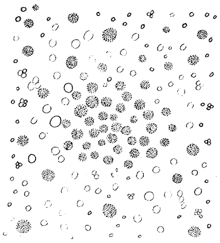
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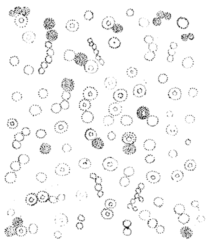
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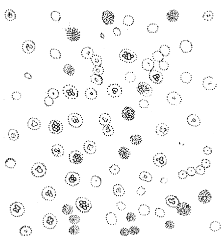
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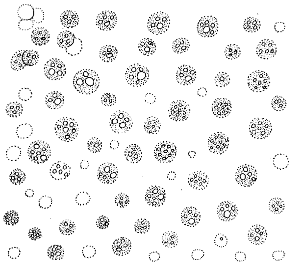

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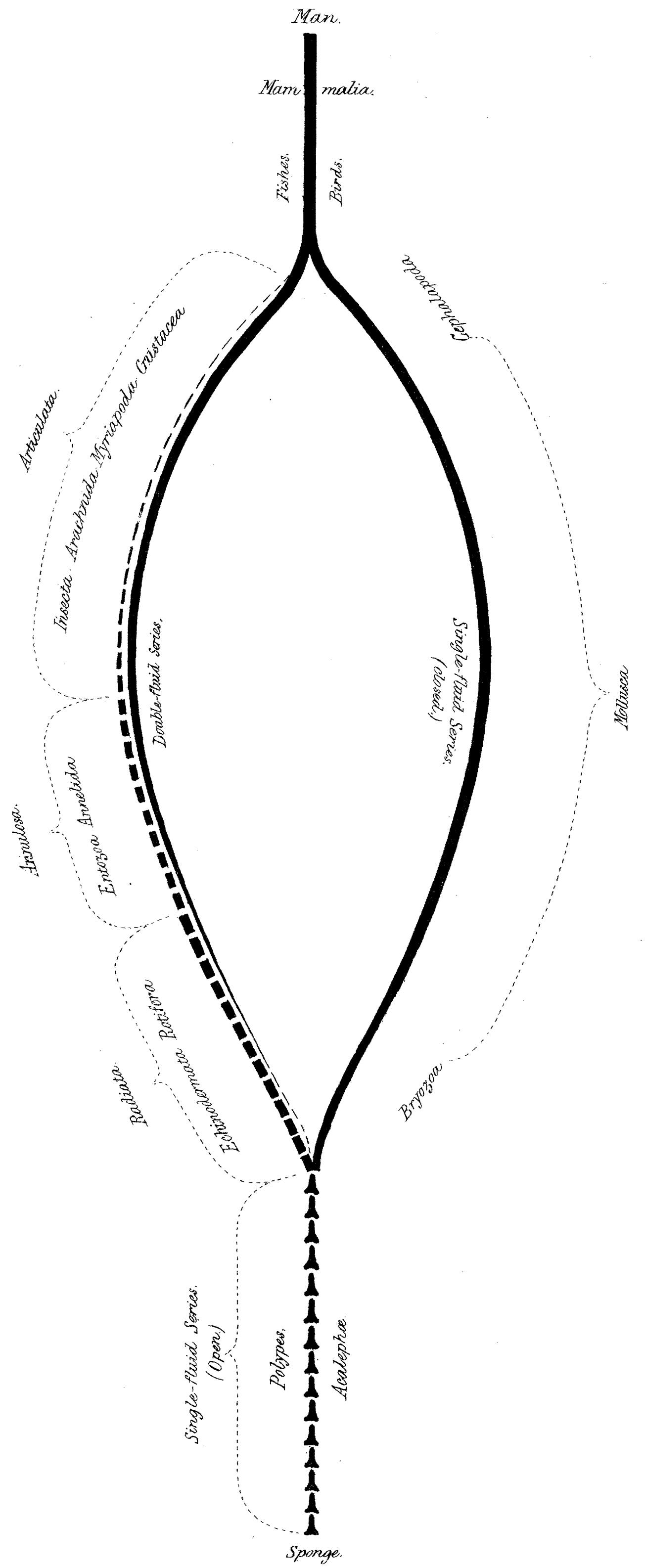
Diagram illustrative of the
Classification of the Invertebrated Animals
on the basis of the Fluids.



Thos Williams M.D. del.

J. Basire, Lith.