CHEMICAL RESEARCHES

ON THE

NATURE AND CAUSE OF CHOLERA.

BY

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AND LECTURER ON CHEMISTRY IN THAT UNIVERSITY.

[*From Volume XXXIII of the 'Medico-Chirurgical Transactions,' published by the Royal Medical and Chirurgical Society of London.*]

LONDON:

PRINTED BY

C. AND J. ADLARD, BARTHOLOMEW CLOSE.

1850.

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Received February 8th.—Read March 12th, 1850.

Although numerous experiments were made upon the fluids of the human body, in those persons affected with spasmodic cholera, during the prevalence of the epidemic of 1832 in this country, yet it seemed desirable that a parallel and more comprehensive set of observations should be obtained during the recurrence of the disease in the winter of 1848-49. In pursuance of this object, the following investigation was commenced at the instigation of the Board of Health; and it is only matter of regret to the author, that in consequence of the pressure of other avocations, the experiments were not carried to the extent which was originally intended. Three objects have been principally kept in view in the following researches into the chemical nature of this remarkable disease:

1. The important constituents of the blood have been carefully examined upon such a scale, as to preclude the possibility of the results which were obtained depending upon mere manual dexterity. The fluids also ejected from the body under the influence of spasmodic cholera have been subjected to chemical scrutiny.

2. The blood and fluids, more particularly the former, have been compared with those of the same class of persons in health, and in some other diseases by new experiments.

3. Some attempts have been made to throw light upon the idea (naturally suggested by the first view of the progress of the disease) of the prevalence of a tangible poison in the atmosphere, which acted as the efficient cause of cholera.

The locality chosen for the investigation appears to have supplied as favorable opportunities of studying the disease as any in the kingdom, since it is believed that, in proportion to the population, a greater number of cases occurred in Glasgow during both epidemics than in any other town in Great Britain.

The results of the chemical investigation of this disease have led to the conclusion, that spasmodic cholera is divisible into three stages:—1. The *laxative* stage (stage of invasion of Annesley, diarrhœal stage of Dr. A. Buchanan), which appears analogous to common laxity of the bowels, depending probably on the transference or diffusion of water from the blood to the mucous membrane of the intestinal canal. 2. The *lymphatic* stage (leucorrhœal of Dr. A. Buchanan, second or advanced stage of Annesley, collapse stage of others), characterised by rice-water dejections, the composition of which more nearly resembles the lymphatic fluids secreted in many diseases into serous cavities than any other animal fluids with which we are acquainted. 3. The *biliary* stage (included in the second stage of Annesley, and identical with the cholerrhœal stage of Dr. Buchanan; stage of reaction of others), characterised by the return of bile to the intestinal canal, and the setting in generally of smart febrile symptoms.

For the sake of perspicuity, these stages will be taken up seriatim, and the analyses presented as much as possible in a tabular form, placed side by side with the results obtained from healthy blood. No chemical experiments were made upon the first stage of the disease, as, when properly managed in a medical point of view, it was usually of short duration, and no opportunities occurred of experimenting upon it; the great object of attraction, both to physician and chemist, being the second or lymphatic stage.

For all the fluids used in this inquiry, the author is indebted to the kindness of Dr. A. Buchanan, Physician to the Clyde-street Cholera Hospital; and to Dr. M'Gregor, Physician to the cholera wards in the Infirmary. It was a fortunate circumstance which thus enabled him to possess the support of one friend, whose excellent paper on the subject of malignant cholera in 1832 first indicated the chemical bearings of the inquiry; and of another, whose researches in pathological chemistry are too well known to require any encomium from him. The figures preceding the numbers in the tables are those originally attached to the cases, and have been continued in order to prevent confusion or error in transferring them from the note-book. It may be proper to add, that the author studied the disease originally in India, when in the service of the East India Company; and that during the recent epidemic, he renewed his acquaintance with the disease in the Glasgow Hospitals, and personally saw most of the cases (and many others), the analyses of whose fluids are given in this paper.

The only chemical experiments on cholera which the author has consulted are those of Dr. Thomas Thomson[1] and Dr. Andrews.[2] The results detailed in these papers, although from a more limited number of analyses than those now to be described, are fully borne out, so far as they go, by the present experiments, and serve to show that the disease, in a chemical point of view, is sufficiently steady.

The method of analysis adopted, consisted in determining the water by evaporating a large quantity of blood, commonly from a quarter to half a pound, and drying it at a temperature of 300° until it ceased to lose weight in a platinum capsule. To prevent scorching, a piece of white paper is placed between the dry mass and the bottom of the capsule as soon as the blood has contracted from the sides of the vessel in which it

[1] Philos. Magaz., vol. xi, p. 347, 1832.

[2] Ibid., vol. i, N. S., p. 295, 1832.

was drying. Any tendency to charring is thus effectually obviated.

The dry residue, after being weighed, was ignited, and the salts remaining digested in water, to separate the soluble from the insoluble salts. The fibrin was determined by washing a weighed portion of blood in a cloth with a weak solution of common salt until the red globules had passed through; the fibrin was then further washed with a plentiful supply of pure water. The specific gravities were usually taken, except in the cases of the serum, by means of the hydrometer, as soon as the blood was drawn. As the object of the inquiry was to determine the condition of the equilibrium of cholera blood compared with that of health, no general attempt was made to ascertain quantitatively that of the more minute constituents of the blood. The disease is obviously attended with too great a disturbance of the system to be characterised merely by alterations in the lesser constituents. The facts are derived from above thirty-four cases.

Second or Lymphatic Stage of Cholera.

Examination of the Blood.

Specific Gravity.—A striking peculiarity in the blood of persons affected with cholera in the lymphatic stage is one which meets us at the very first step in the chemical inquiry, viz., the great augmentation in the specific gravity of that fluid. This is exhibited in the following table, in contrast with healthy blood obtained from healthy persons about the same period, and in the same class of society:

Table I.

Specific gravity of Blood.

		Cholera.	Health.	
			Female.	Male.
Case V.—1.	(Female.)	1074	1052	1054
2.	„	1068		
„ XI.	„	1065[1]		

[1] Dr. Macgregor, in 190 cases, often found the specific gravity as high as 1078.

TABLE II.

Specific gravity of Serum.

	Cholera.	Health.
Case V.	1058	1028
„ XIII.	1042	

Ratio of Serum to Clot.—The table shows that the aberration from health is not great; but this in some measure depends upon the increase in the weight of the serum, as indicated by its specific gravity.

TABLE III.

	Cholera.		Health.			
	Expt.		Female—Expt.		Male—Expt.	
Case XI.—Serum	1006 grs.	438	1123 grs.	423·9	1220 grs.	455·2
Clot	1290 „	562	1526 „	576·1	1460 „	544·8
	2296	1000	2649	1000·	2680	1000·

Constituents of the Serum.—In cholera it appears that the amount of water is inferior to that contained in healthy serum:

TABLE IV.

	Cholera.		Health.			
	Expt.		Female—Expt.		Male—Expt.	
Case XI.—Water	881 grs.	876	1008 grs.	897·6	1105·5 grs.	909·7
Albumen and Salts	125 „	124	115 „	102·4	114·5 „	90·3
	1006	1000	1123	1000·	1220·	1000·

Composition of the Clot:

TABLE V.

	Cholera.		Health.	
	Expt.		Male—Expt.	
Case XI.—Water	905 grs.	702	1035 grs.	709
Solids	385 „	298	425 „	291
	1290	1000	1460	1000

It appears, therefore, that in this case the amount of serum detained by the clot is nearly the same as in health. If the whole of the water in the clot be viewed as serum, then the composition of the clot in cholera and health is:

Table VI.

	Cholera.	Health.
Serum	801	793
Globules, Fibrin, and Salts	199	207
	1000	1000

Amount of Water and Solids in the Blood of the Lymphatic Stage of Cholera.

The following table was made by experiments, in which a quantity of blood was dried at the temperature of 300° F. until it ceased to lose weight. The first three columns give the exact result of the experiments in grains, and the last two columns the amounts reduced to a thousand parts :

Table VII.

	Water.	Solids.	Total Blood.	Per 1000 parts. Water.	Solids.
Case IV.—1st Bleeding—	1428	592	2020 grs.	707	293
2d "	2015	905	2920 "	690	310
" V.—1st "	2322	1003	3325 "	698	303
" VI. "	425	143	568 "	748	252
" VII. "	1421	408	1829 "	777	223
" VIII. "	1602	798	2400 "	668	332
" XI. "	1786	510	2296 "	778	222
" XIII. "	2544	950	3494 "	729	271
Mean of eight specimens . .				724	276
Healthy blood—Female	2104	545	2649 "	794·26	205·74
Ditto Male	2140	539·5	2680 "	798·7	201·3

In Case IV the first bleeding was made on the fourth day from the arm. The blood in the second bleeding was extracted from the foot, and the blood when drawn exhibited a slightly buffy coat. In Case V the blood was taken on the fourth day. In Case VI but a small portion of serum separated when the blood was allowed to stand in the usual manner, and yet the quantity of water in the blood is greater than in many other cases. In this patient the temporary influence of galvanism in rousing the action of the heart was well exhibited, but the effect, as in many other cases where it was applied, proved merely ephemeral.

In drawing up the preceding table every attention has been directed to secure the introduction only of such cases as were undoubtedly advanced to the collapse stage, but had not proceeded to the condition of reaction, or, as it is termed in this paper, the biliary stage. It is not always easy to point out the exact line of demarcation between the two stages of the disease, since the collapsed condition characterised by the subtraction of water from the blood may have ceased, and yet the biliary matter may not have commenced to flow; and a comparison of this table with that under the biliary stage will at once convince us of the rapidity with which the blood recovers its natural equilibrium in reference to the relation between its solid and fluid constituents.

For the reasons previously specified, the following cases have been separated and placed in a table by themselves, as the blood in these instances was taken from the heart—personally—as it seemed an interesting point to compare the blood, as it is described to be *tarry* after death, with the blood taken from the veins during life:

TABLE VII.*

	Experiment.				Per 1000 parts.		
	Blood.	Solids.	Water.	Salts.	Solids.	Water.	Salts.
Case I.—2000 grs.		612	1388	15·	306	694	7·5
„ G.— 370 „		66	304		178	822	
„ H.— 672 „		292	380	6·9	433	567	10·26
			Mean of three cases		305	694	8·88

The consequence fairly deducible from the eight observations enumerated in the table is, that in the lymphatic or collapse stage of cholera, the watery portion of the blood has diminished by at least 7 per cent.; so that if we were to consider with some physiologists, the total amount of the blood in the human body to approach 22 lbs., it would appear, that in the spasmodic cholera, at least $1\frac{1}{2}$ lbs. of the watery part of the blood have been extracted from that fluid and poured into the intestinal canal. This, however, is taking the most favorable view of the circumstances. But if we estimate the amount in some of those cases where the diminution of fluid in the blood is at a minimum, then the per centage reduction will reach as high as 13. The disturbance in the natural balance of the constituents of the blood in this disease will perhaps be as well understood by taking the ratio between the water and the solids, and then comparing it with the same relations in the healthy condition:

Cholera—Relation of solids to water	. .	1 to 2·62
Health Ditto	. . .	1 to 3·91

During the prevalence of cholera, a specimen of blood, obtained by hemorrhage from the nose, was put into the author's hands by his friend Dr. Pagan. The patient laboured under an affection of the mucous membranes of the air tubes. It is the only specimen of blood which he has hitherto found to assimilate to that of the lymphatic stage of cholera:

TABLE VIII.

	Expt.	
Water . . .	139·9	692·30
Salts . . .	0·6	2·97
Globules, Albumen, Fibrin . .	61·6	304·73
	202·1	1000·

In this case we have the relation of solids to water even closer than in the case of cholera:

Ratio of solids to water . . . 1 to 2·25

Amount of Globules, Albumen, and Fibrin in the Blood of the Lymphatic Stage of Cholera.

From the determination of the fact, that the quantity of solid matter in the blood is greater in the lymphatic stage of cholera than in health, it becomes important to inquire if the solids are equally present in the usual proportions, or in other words, if it be true, as has been asserted, that there is an increase of some of the solids of the blood and a diminution of the normal quantity of saline matter. This table is obtained by deducting from the solids in Table VII already given, the amount of saline matter ascertained by experiment.

TABLE IX.

		Experiment.		
		Total Blood.	Globules, Albumen, and Fibrin.	Globules, &c. per 1000.
Case	IV.	2020 grs.	575	284·69
,,	V.	3325 ,,	970	291·78
,,	VI.	568 ,,	140	246·70
,,	VII.	1829 ,,	385	204·44
,,	VIII.	2400 ,,	775	322·92
,,	XI.	2296 ,,	495	215·47
,,	XIII.	3494 ,,	923	266·33
			Mean of seven cases . .	261·76

Healthy Blood.

	Total Blood.	Globules, &c.	Globules, &c. per 1000.
Male . . .	2680 grs.	522·4	195
Female . .	2649 ,,	529·5	200

TABLE X.

Amount of Fibrin.

	Experiment.		
	Blood.	Fibrin.	Per 1000.
Case IV.	2920 grs.	17	5·82
,, XIII.	702 ,,	1·04	3·27
Mean			4·54
,, of healthy blood (Lecanu)			2·95

TABLE XI.

Amount of Globules and Albumen.

	Globules and Albumen.
Case IV.	278·87
,, XIII.	263·06
Mean	270·96
Mean of healthy blood (Lecanu)	200·55

Although we observe in this case some difference in the ratio of the solid constituents, as exhibited in the following table, it is probably not sufficient to constitute an aberration from the normal standard of any value, since we find even in health variations in the amount of fibrin present.

TABLE XII.

	Fibrin.		Albumen and Globules.	Water.
Cholera . . .	4·54		270·96	724
Health . . .	2·95		200·55	790
Ratio in cholera	1	to	59·86	159
,, health	1	to	66·80	263
Differences			6·94	104

The preceding result is obtained by dividing each of the numbers by the amount of fibrin. There is strong reason to suspect, from the nature of the chemistry of the disease, as it will afterwards be developed in the course of this paper, that the colouring matter or globules will in some cases be preternaturally augmented, as we find frequently considerable discharges of albumen in the excreted fluids. But the relative decrease or increase of these two proximate principles must undergo great variations, as we not unfrequently find blood globules in the rice-water evacuations. Whether these be derived from the sanguineous circulation, or from the minute vessels of the mucous membrane over which the epithelium and mucous membrane have been abraded in the course of the disease, is doubtful. The appreciation of minute differences in the amount of these constituents is at present a desideratum in chemistry. In inquiring into the chemical constitution of the blood in health and disease, it is of more consequence to attend to the relation in which these exist to each than to their absolute quantity. This is obvious from a consideration of the equilibrium of the food, that is, of the relation subsisting between the proximate constituents; but which it is unnecessary to enter into here, as it has been elsewhere treated of at length in another work.[1]

In the preceding table, the fibrin appears to be greater in cholera, relatively to the other solids, than in health. To

[1] Experimental Researches on Food, chapter ix.

preserve the exact ratio, the fibrin ought to have been 3·91. But to those who consider the mechanical method adopted for obtaining the fibrin, the difference between 3·91 and 4·54 may not appear abnormal. It may be stated, however, that the mean amount of fibrin obtained from four cases (including the two preceding and two other cases) introduced under the stage of reaction, was 3·65 per 1000 of blood; and that one of these cases yielded exactly 3·91 per 1000 of fibrin. From these facts, the conclusion seems legitimate, that so far as the organic constituents of the blood in cholera are concerned, the analyses which have been previously given lead to the inference that there is nothing abnormal in the amount of these organic principles; and that, so far as we have already proceeded with the inquiry, the disease, as affecting the blood, consists simply in a diminution of water.

Salts in the Blood of the Lymphatic Stage of Cholera.

We now approach a very interesting inquiry in the investigation of the chemistry of cholera; in reference to which much has been written, and much variety of sentiment prevailed. According to one view, cholera is characterised by a deficiency of the natural saline matter of the blood; and hence it has been recommended, that to make up for the removal of this constituent, a solution of common salt should be injected into the circulation. There is, however, an error here at the outset, in the recommendation of this practice without an accurate analysis of the salts which have been removed by the disease. For it is not probable, *à priori*, that one soluble salt should be removed from the circulation without a certain proportion of other saline ingredients. In order to throw some light on this question, the total amount of salts has first been determined, and then the relative quantities of insoluble and soluble matter, of which the total saline constituents consisted, have been ascertained, so as to determine in how far the saline treatment of cholera is founded on rational principles. In the following table will be found the total amount of saline matter in the blood of different patients:

TABLE XIII.

	Experiment.		
	Blood.	Salts.	Per 1000.
Case . . IV.	—2020 grs.	17	8·41
" V.	—3325 "	33	9·92
" VI.	— 568 "	3	5·30
" VII.	—1829 "	23	12·56
" VIII.	—2400 "	23	9·58
" XI.	—2296 "	15	6·53
" XIII.	—3494 "	26·8	7·67
	Mean of seven cases . .		8·56
Healthy blood (female)	2649 grs.	15·5	5·81
" " (male)	2680 "	17·1	6·38

From these results it is sufficiently obvious, that the total amount of saline matter in cholera considerably exceeds the natural quantity, the ratio of the salts in healthy blood being to those of cholera blood as 1 to 1·4. There still remains the determination of the relative proportion of insoluble to soluble salts, or of the bone salts compared with those which are principally useful in the circulating and muscular fluids. The insoluble salts consist of phosphates of lime, magnesia, and iron; the soluble of chlorides of sodium and potassium, trisphosphate and sulphate of soda.

TABLE XIV.

		Salts.			Per 1000.		
	Blood.	Insol.	Sol.	Total.	Insol.	Sol.	Ratios.
Case V.	—3325	6·85	26·15	33	2·06	7·86	1 to 3·81
" VIII.	—2400	3·45	19·55	23	1·43	8·15	1 to 5·7
" XIII.	—3494	7·47	19·33	26·8	2·13	5·54	1 to 2·59
		Mean . . .			1·87	7·18	1 to 3·83
Healthy blood, female . .	2649	2·87	12·63	15·5	1·08	4·76	1 to 4·40
Do. male . . .	2680	3·41	13·69	17·1	1·27	5·11	1 to 4·02
					Mean . . .		1 to 4·21

From this table we infer, that the equilibrium of the saline constitution of the blood in cholera is decidedly disturbed; for while there is in the same quantity of blood a larger amount both of earthy and soluble salts, there is a less quantity of the soluble salts in proportion to the earthy ingredients. The method of restoring the balance which has thus been interfered with would not be by adding more soluble salts, which are already in excess (as is apparent by comparing the various numbers in the sixth column), by upwards of one third, but by subtracting a certain amount of the earthy substances. It is not, however, to be supposed that any such mode of treatment could be attended with any benefit; for omitting the fact, that besides saline matter, albuminous substances also escape from the blood in this stage of the disease, it must be obvious, on even a cursory examination of cholera, that the condition of the blood is merely a symptom of the disease—an effect of some powerful atmospheric cause of which hitherto we have not been permitted to take cognisance. At the same time it must be admitted, that our knowledge of disease in general is in a great measure confined to the symptoms, and that it is only by a due consideration of symptoms by a progress of ascent, that we can ever expect to arrive at a knowledge of the cause of the symptomatic disturbance. From the preceding details, we are now enabled to construct a table which will afford a view of the average amount of the different constituents of cholera blood in the lymphatic stage. A parallel column of the ingredients of healthy blood from Lecanu is given for the sake of comparison:

TABLE XV.

	Cholera.	Health.
Water	717·8	790·00
Fibrin	4·5	2·95
Globules and albumen	268·8	199·55
Insoluble salts	1·8	1·00
Soluble salts	7·1	6·50
	1000·0	1000·00

If we compare the relation of the inorganic to the organic constituents of the blood in these two columns, we shall observe that there is comparatively but a slight difference in the ratio in cholera as compared with health. The disturbance in the equilibrium lies in the ratio between the soluble and insoluble salts:

Ratio of Salts to Fibrin, Globules, and Albumen.

Cholera	1 to 30
Health	1 to 27

The following table gives the constituents of the soluble salts in cholera in 1000 parts, but it must be viewed merely as an approximation, as, from circumstances, the results were derived from limited sources:

TABLE XVI.

	Cholera.	Health. (Enderlin.)	Health. (Marchand.)
Chlorides of sodium and potassium	1·71	3·66	3·63
Trisphosphate of soda	2·21	1·47	0·72
Sulphate of soda	1·01	0·16	0·52
Carbonate of soda	0·61	0·31	0·94
	5·54	5·60	5·81

According to this table, the amount of common salt in cholera blood falls below that which is found in a state of health. In another experiment 1·46 of alkaline chlorides were obtained from 1000 parts of blood. But the preceding figures also show, that in different healthy individuals, the ratio between the individual soluble salts varies greatly. It was this fact which seemed to render a very elaborate analysis of the blood salts a work of supererogation.

Fæces in the Lymphatic Stage of Cholera.

The excrementitious matter in the collapse stage of cholera has attracted a large share of attention, and its remarkably liquid consistency has tended to originate much speculation regarding the nature, source, and consequently the character of the disease. The descriptive title of *rice-water* evacuations is peculiarly applicable to the matter excreted by the intestines in this stage of the disease; but it does not appear that their true nature has yet been deduced from accurate chemical experiments. The enormous quantities of fluid evacuated generally in this stage, although in some measure, perhaps, frequently exaggerated in description, by complication with the fluid swallowed by the patient, to assuage the urgent symptoms of thirst, are sufficient to arrest attention, even irrespective of the violent throes of agony with which the disease is accompanied. The fluids are always characterised by the presence of what have been termed flocculi. These have generally been assumed to be coagulated albumen. But careful examination under the microscope has demonstrated these masses of organic matter to be chiefly epithelial scales, derived, without doubt, from the surface of the intestinal mucous membrane, as in the case of the excretions of infants at the breast. These fluids are almost always alkaline; in one instance, however, the fluid was strongly acid, after being kept for twenty-four hours, and on the removal of the cork of the bottle, a quantity of carbonic acid was evolved. It is quite possible that the fermentation was due to the presence of sugar in the intestinal canal, derived from milk, which was freely administered, in mixture with eggs, to the patients in the cholera hospitals of this city. The analyses of these fluids will be arranged in two tables. In the *first* will be placed those cases which afford the type of the most frequent rice-water evacuations, and the *second* will exhibit a view of those analyses where a larger amount of organic matter was present than usually occurs in the fluids excreted.

Table XVII.

	Expt. Fluid.	Residue.	Per 1000 Parts. Sp. Grav.	Residue	Water.
Case	A.— 500 grs.	5· grs.	....	10·	990
„	B.—7000 „	78· „	1010	11·1	988·9
„	C.—1000 „	15·9 „	....	15·9	984·1
			Mean per 1000 ...	12·33	987·66

Table XVIII.

Table of Organic Matter and Salts.

	Expt. Organic Matter.	Salts.	Per 1000. Organic M.	Salts.	Water.
Case A.— ...	5·	...	10·	...	990
„ B.— ·23	.	55·	3·3	7·8	988·9
„ C.—10·2	..	5·7	10·2	5·7	984·1
		Mean	6·75	6·75	987·6

Ratio of Solids to Water, 1 to 73.

The organic matter named in these tables generally consists of a greater or smaller amount of albumen; for on evaporation in vacuo, a whitish yellow residue was obtained, which, on being treated with water, yielded a solution, coagulating on boiling and by the addition of acids. Usually, the fluids, as evacuated, when allowed to settle, yielded, by boiling, or the addition of an acid, distinct evidence of the presence of albumen. The quantity, however, in true rice-water cases was generally insignificant. On comparing these results with the analyses of the various fluids which make their appearance in serous and mucous cavities, as a result of diseases, it would almost seem that the intestinal mucous membrane had in this disease assumed the functions of a serous membrane, since the liquid evacuated bears a close resemblance, in composition, to the fluids deposited in local dropsies, and does not correspond, as has been generally asserted, with the serum of the blood. It deserves attention, however, that the natural fluids of the mucous membranes bear a close resemblance to those of the serous tissues, inasmuch as they consist of an alkaline fluid, with a small percentage of salts dissolved in a large amount of water. The following table exhibits the parallelism of the fluids of the rice-water stools, and serous fluids, effused in hydrocele and hydrocephalus, together for the sake of comparison with the general constitution of the pure serum of healthy blood.

Table XIX.

	Salts.	Organic Matter.	Water.	Observer.
1. Serum.	9·2	. . . .	. . . . .	Marcet.
2. Ditto	11·00	89·	900·	R. D. T.
3. Ditto.	9·	. . . .	. . . . .	Lecanu.
4. Cholera Fluid. .	6·75	6·75	986·5	R. D. T.
5. Hydrocele „	7·82	. . . .	. . . . .	Ditto.
6. Hydrocephalus	8·66	1·52	989·82	John Tennent.

It was from the analogy of these fluids, in reference to their chemical composition, that the term lymphatic has been given to this stage of the disease. The interesting researches of Dr. A. Buchanan have demonstrated, that what are usually termed serous effusions are in reality lymphatic, since they all contain fibrin, which can be made beautifully apparent by mixing them with blood serum, or simply by the introduction of certain moist solids into them.

The nature of the salts in the rice-water evacuations is precisely similar to that of the saline matters found in the serous fluids of hydrocele and hydrocephalus. In one extract, B, there was found 3·15 grs. per 1000 of common salt, mixed with carbonate of soda, some lime, with earthy phosphate and alkaline sulphate. In another extract, C, there was 0·912 common salt; and in G, 1·66 of the same salt. The earthy phosphate was indicated by obtaining a precipitate, on adding ammonia to the acid solution of the salts of the fæces, and the alkaline phosphate, by obtaining distinct crystals of ammonia phosphate of magnesia when a salt of magnesia was added to the solution of the salts, after dissolving in it sal-ammoniac. The characters which have been now detailed apply to the usual rice-water dejections, but cases frequently occurred in which the amount of organic matter was much more considerable, although the proportion of salts was not materially augmented.

Table XX.

	Sp. grav.	Organic Matter.	Salts.	Water.
Case	D.—1021	59·	8	933
„	E.—1010	20·98	7·35	971·67
„	K.—	52·5		947·5

In D the quantity of epithelial scales was great. When they were allowed to subside, the supernatant fluid was poured off, and exposed to a temperature of 212°. The whole coagulated into a mass in a manner corresponding with the serum of blood, and yielded a similar odour; thus exhibiting the presence of a large amount of albumen. From this character the fluid corresponded in some measure with blood serum; but still it will be observed, on a comparison with serum as given in the preceding tables, the albumen or organic matter in this fluid fell far short of that which exists in serum. And the same observation applies to the salts present in the two fluids. The following table shows, however, that serous or lymphatic fluids vary very considerably in composition. The experiments were made for the purpose of illustrating this inquiry:

TABLE XXI.

	Organic Matter.	Salts.	Water.	Sp. grav.	
Hydrocele fluid	97·4	6·8	895·8	1029	Mr. Carlyle.
"	42·4	7·1	950·5	1019	

In this table we find that the saline constituents approach even more closely than the previous data to the results obtained in cholera, although the albuminous matter varies. In a case of rachitis, the organic matters bore to the salts the relation of 1 to $5\frac{3}{4}$, which approximates the ratio found for hydrocephalus in Table XX. In E the fluid smelt alcoholic, and contained abundance of sugar, as indicated by the copper test. This constituent, it has been already stated, might possibly be derived from the albuminous mixture of eggs and milk, used as drink for the patients. In K the evacuation was derived from Case IV, in the table of the analyses of blood. It possessed a white gruelly aspect; and when evaporated to dryness under the vacuum of an air-pump, a residue was obtained which yielded to water a solution which was coagulated by heat and acids.

Urine in the Lymphatic Stage of Cholera.

When death occurs in this stage, the largest quantity of urine which we have seen taken from the bladder was about a drachm; but usually the secretion may be said to be totally suppressed. On testing the minute quantities which were obtained, they seemed to contain the ordinary constituents.

Third or Biliary (Reaction) Stage of Cholera.

Blood in the Biliary Stage.

As soon as the lymphatic stage has terminated favorably, and the patient is so fortunate as to reach the third stage, the blood begins to assume its normal condition. The following table exhibits the specific gravity of the serum in this stage:

Table XXII.

		Sp. grav. of Serum in Biliary Stage.
Case	IX. . . .	1027·9
,,	XII. . . .	1027·9
	a. . . .	1028·9
	b. . . .	1027·9
	c. . . .	1026·3
	Mean	1027·7

Health from 1027 to 1029.

From the next table we discover, that the remarkable diminution of the watery element of the blood is but of short duration. The violent ejection of the fluid contents of the intestines subsides, and a greenish or yellow matter is voided, much more consistent in its nature. At the same period, the amount of water in the blood begins to resume its normal proportions, and if the disease terminates favorably, the blood speedily acquires its natural composition.

Table XXIII.

Water and Solids of Blood in Biliary Stage.

	Experiment.			Per 1000.	
	Blood.	Solids.	Water.	Solids.	Water.
Case IX.	—2477 grs.	476	2001	193	807
,, X.	—2096 ,,	437	1659	208	792
,, XII.	—2353 ,,	495	1858	210	790
Mean of three cases . . .				203	797
Mean health—Male . . .				201·3	798·7
,, ,, Female . . .				205·74	794·26
Mean—Lymphatic Stage .				276	724

In Case IX the patient was 62 years of age. The blood had a decided buffy coat—a presumption of abnormal oxidation—and therefore of an inflammatory condition. In Case X, the blood was from the temporal artery, but mottled in appearance, as if imperfectly oxidated; a character which attracted frequent attention during the occurrence of cholera. In Cases IX and XII the specific gravity of the serum, it will be observed by Table XXII, was natural. In Case IX the following was the relation between the serum and clot:

TABLE XXIV.

	Expt.	
Serum . . .	1360 grs.	550
Clot	1117 „	450
	2477	1000

With regard to the composition of the serum and clot in Case IX, the following table yields the result:

TABLE XXV.

Composition of Serum and Clot in Biliary Stage.

	Expt. Serum.	Serum.	Expt.—Clot.	
Water	1200 grs.	882	808	723
Solids	160 „	118	309	277
		1000	1117	1000
Health.—Water		903		709
„ Solids		97		291
		1000		1000

From this table it appears, that the constituents of cholera blood in this stage and of healthy blood closely approximates; the differences being quite within the range of variations even in healthy blood.

TABLE XXVI.

Amount of Fibrin in Biliary Stage.

	Blood.	Fibrin.		
Case IX. . . .	2477 grs.	4	=	1·61 per 1000
„ X. . . .	2096 „	8·2	=	3·91 „
Mean				2·76
Mean of lymphatic stage . .				4·54
Mean of health				2·95

There is observable here great irregularity in the amount of fibrin, and the anomaly in Case IX of a diminution of fibrin over the healthy stage, instead of an increase, as usually happens in inflammatory complaints. But, probably, the great shock given to the system by such a depletory stage as the lymphatic, will afford a satisfactory explanation of the interference with the permanent equilibrium of this fluid.

TABLE XXVII.

Globules, Albumen, and Fibrin in Biliary Stage.

	Experiment.		
	Blood.	Globules, &c.	Per 1000.
Case IX.	2477 grs.	477	184·49
„ X.	2096	420	200·29
„ XII.	2353	479·8	203·54
Mean of biliary stage			196·10
Mean of lymphatic stage			261·76
Mean health			197·42

TABLE XXVIII.

Salts in the Blood of the Biliary Stage.

	Experiment.			Per 1000.		
	Blood.	Insol. Salts.	Sol. Salts.	Insol.	Sol.	Total Salts.
Case IX. . .	2477	4	15	1·61	6·06	7·67
„ X. . . .	..	..	..	..	..	8·11
„ XII. . .	2353	2·5	12·7	1·06	5·40	6·46
Mean				1·33	5·73	7·44

Ratio in biliary stage . . . . 1 to 4.3
„ lymphatic stage . . 1 to 3·83
„ health . . . . . . 1 to 4·2

From the mode in which these tables are arranged, it is at once apparent, that the blood of patients in the biliary stage has regained the water which it possessed in the natural state. Indeed, it would seem that some excess of water is present, while the other constituents are rapidly regaining their normal relations to each other. This is well exhibited in the ratio of the two classes of salts to each other, and also in the relative proportions of organic constituents and water.

Ratios of Fibrin to Globules and Albumen and Water.

Biliary stage . . .	1 to 68·7	288
Health	1 to 66·8	263

It must be, however, always borne in mind, that the patients from whom these fluids were obtained were all undergoing medical treatment, and were subjected to certain kinds of diet; the princlpal ingredient of which, however, was water. The mean composition of the blood in the biliary stage, according to the previous experiments, will therefore stand as in the following table, as compared with the lymphatic stage and with health:

Table XXIX.

Composition of the Blood in two stages of Cholera and in Health.

	Biliary Stage.	Lymphatic Stage.	Health. (Lecanu.)
Water	800	717·80	790·8
Fibrin	2·76	4·5	2·95
Globules and Albumen .	190·18	268·8	199·5
Insoluble salts	1·33	1·8	1·
Soluble salts	5·73	7·1	6·50
	1000·00	1000·0	1000

It has been conceived by some authorities, that the stage of reaction bears a close relation to fever of a typhoid type. To ascertain if the chemical conditions of the disease would bear out this surmise, a specimen of blood was taken from a well characterised case of spotted typhus in the Infirmary of this city. The results of analysis give for the composition of typhus blood:

Table XXX.

Composition of Typhus Blood.

	Expt.—Typhus.		Biliary Stage.
Water	731·4	837·8	800
Globules, Albumen, and Fibrin .	145	158·79	192·94
Salts	3	3·41	7·06
	879	1000·00	1000

The idea of their identity is certainly far from being borne out. At the same time, it is to be observed, that in the reaction stage there is a decrease of the salts when compared with the preceding or lymphatic stage, while the water has increased above the natural state; and that these are the actual results, although much more extensive in degree, in typhus.

Fæces in the Biliary Stage of Cholera.

The biliary stage is introduced by the appearance of a green or yellow tinge in the evacuations. When the matter is dried in vacuo it loses a great amount of water, varying in the numerous trials which have been made in the present inquiry from 95½ to 36 per cent. The solid residue, when digested in alcohol, yields up a large proportion of substance soluble in that menstruum. In Case G, 1000 grains of fæces left 64 of residue. This gave up to alcohol 27 grains, which afforded a pink tint with sugar and sulphuric acid, although not a very striking indication; and when treated with muriatic acid, a small portion of resinous matter was deposited. From these characters it may be inferred that the fæces contained at least a trace of bile. In cases where death occurred during the biliary stage, the intestines were found to contain generally a considerable quantity of yellow feculent matter throughout the course of the small and large intestines. The fluid portion afforded an alkaline reaction, and through it were diffused white flocks.

TABLE XXXI.

Water and Solids in Fæces.

			Per 1000.		
Fæces.	Solids.	Water.	Solids.	Water.	Ratios of solids to Water.
Case F.—1000 grs.	45	855	45	855	1 to 19
„ G.—1000 „	64	936	64	936	1 to 14·62
„ H.— 83 „	13·2	69·8	15·9	841	1 to 5·3
Mean . .			89	877	1 to 9·8
Lymphatic stage . .			13·5	986·5	1 to 73
Health—(Berzelius)			267	733	1 to 2·75
Cow—(R. D. T.) . .			117	883	1 to 7·5

From this table it appears that there is great diversity in the ratios of the solid to the fluid constituents of the intestinal evacuations, even in animals in a state of health. But the remarkable contrast of all the preceding numbers with the evacuations in the collapse stage of cholera, is deserving of notice, and establishes a sufficient character.

TABLE XXXII.

Salts in the Fæces of Biliary Stage.

	Fæces.	Salts.	
Case F.	—1000	10	
Health	,,	12	(Berzelius.)
Cow	,,	17·5	(R. D. T.)

Urine in the Biliary Stage.

The urine was sometimes of a paler colour than the tint which it assumes in health; but generally no deviation from the normal state could be detected merely by an examination of the colour or consistence of the excretion. The specific gravity is, perhaps, somewhat lower than the standard of health.

TABLE XXXIII.

Specific Gravity of Urine in Biliary Stage.

Case	V.—1018	Fourth day of admission.
,,	V.—1017	(Fourth day of admission.)
,,	G.—1016	Ditto ,,
,,	H.—1015	Sixth day ,,
,,	I.—1004	
Health	1019	

The healthy standard is here taken from a mean of 158 observations made by the author upon the urine of health. From this comparison we observe that the specific gravity of the urine in the biliary stage, except in one case, falls but slightly below the normal condition, perhaps the variation is not greater than happens in the same individual in one day. But, by the copious use of water, even in the healthy state, the lowest specific gravity may almost be reached without the production of any other abnormal symptom in the system. In several cases albumen was found in the urine in this stage, although, on a post-mortem examination, we could observe no trace of granulation nor unnatural structure. In case G nearly five parts per 1000 were found of albumen, on the fourth day after admission. The albumen, however, soon disappeared in this and the other cases. In this case, however, the patient had been taking diuretics, and a turpentine enema had been administered.

TABLE XXXIV.

Water and Solids in Urine of Biliary Stage.

	Solids.	Water.	
Case G.	32	968	containing albumen.
Health (Becquerel)	31·2	968·8	

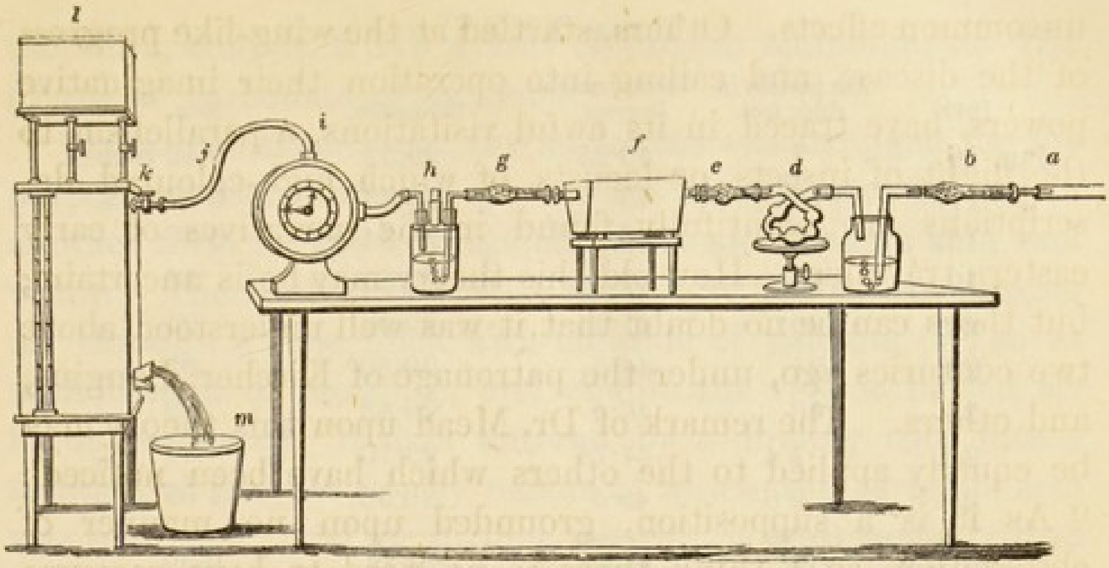
From this comparison it appears that there is scarcely any deviation from the urine of health, except in the amount of urea, which is at first deficient. The occurrence of albumen in the urine is rather a remarkable symptom, connecting, as it does, cholera with scarlet fever, in the latter stages of which disease we have fluids effused into the cells, just as we have in cholera fluid effused, so to speak, into the intestines.

CONDITION OF THE ATMOSPHERE DURING THE PREVALENCE OF CHOLERA.

It has been a prevalent idea, that cholera is produced by some species of poison existing in the atmosphere. On many occasions this view has been advocated very much upon the principle adopted by the vulgar, of ascribing effects to certain causes, of the nature of which they are themselves not cognizant. Thus heat, light, and cold have all been called in to assist in the production of the disease; and, lastly, of the imponderables, electricity has been named as being more mysterious, and therefore more calculated to originate uncommon effects. Others, startled at the wing-like progress of the disease, and calling into operation their imaginative powers, have traced in its awful visitations, a parallelism to the flight of insects, or locusts, of which high-coloured descriptions are plentifully found in the narratives of early eastern travellers. How old this theory may be is uncertain; but there can be no doubt that it was well understood above two centuries ago, under the patronage of Kircher, Langius, and others. The remark of Dr. Mead upon this theory may be equally applied to the others which have been noticed: "As it is a supposition, grounded upon no manner of observation, so I think there is no need to have recourse to it."

For the purpose of gaining either positive or negative evidence as to the existence of poison in the atmosphere, in infected districts, during the prevalence of cholera in Glasgow, the following experiments were instituted. The methods which chemistry can supply for the purpose, in the present state of our knowledge, must presuppose that the so called poison is a tangible organic body: such being the character of all animal poisons. It must be capable of acting on the circulating and nervous systems, otherwise it is not a poison, but must belong to some unknown category, respecting which it would be in vain at present to speculate.

To search for atmospheric poisons upon a minute scale would have served no purpose whatever. An apparatus was therefore arranged by which large quantities of air could be subjected to the influence of chemical reagents. The propelling or suctive powers by which the air was conveyed through the tubes was the common principle of aspiration. A large gas-holder was filled with water, and connected with a series of tubes through which the infected air passed, when the water was allowed to flow from the lower aperture of the gas-holder. The accompanying figure affords a view of the apparatus as arranged for the most difficult testings of the air:



a. Tube for conducting the infected air.
b. A tube filled with chloride of calcium to dry the air.
c. Bottle with water or barytes water.
d. Liebig's bulbs, filled with barytes water, or caustic potash.
e. Chloride of calcium tube.
f. Furnace for organic analysis, containing a Bohemian tube filled with oxide of copper.
g. Chloride of calcium ,ube.
h. Bottle with barytes water.
i. An experimental meter for measuring the amount of air passed.
j. A flexible tube.
k. A stop-cock uniting the meter with the gas holder.
l. Gas holder filled with water.
m. Vessel into which the water flows from the gas-holder when the stop-cock K is open.

The first series of experiments was made to ascertain if any solid body could be separated from a large quantity of air by passing it through acidulated water. The apparatus for this experiment simply consisted of tube *a* and bottle *c*, connected with the meter and gas-holder, or the tubes from *d* to *h* inclusive were omitted. The tubes were connected together by caoutchouc tubing, and these junctions were further effectually rendered air-tight by a coating of gun-cotton dissolved in ether (collodion), which appears to promise many advantages in delicate chemical manipulation. On removing the plug from the lower extremity of the gas-holder, and turning the stop-cock *k*, the air immediately passes through the dipping-pipe into the bottle *c*. The following table exhibits a register of the quantity of air passed during a number of days :

Table XXXV.

1849.	Air passed, in cubic feet.	Thermometer. Degrees.	Barometer.	Rain.
Jan. 16.	7	43·25	29·51	0·42 inches.
17.	16	45	29·33	0·12 „
18.	16	46	29·34	0·06 „
19.	20	47	29·60	34 „
20.	20	41·25	29·96	03 „
22.	21	44·5	29·50	07 „
23.	16	46·5	29·83	29 „
24.	7·4	47·75	29·70	01 „
25.	2·6	49·5	29·50	1·05 „
Total .	126	45·63	29·58	2·39 „
		Mean.	Mean.	Mean.

The distilled water in the bottle *c* having been acidulated with pure muriatic acid prepared for the purpose, it was expected that any solid matter, if it existed in the atmosphere in any appreciable amount, would be condensed and entangled by the water. The acid was added for the purpose of detaining the ammonia. The water, after the expiration of the experiment, was apparently perfectly clean, and without deposit. It was evaporated by a gentle heat over a water-bath. No trace of turbidity or deposit exhibiting itself, the fluid was evaporated nearly to dryness, without exhibiting any appearance of precipitate, with the exception of an incipient saline crust. A small portion of an alcoholic solution of bichloride of platinum was now added, when a distinct yellow crystalline powder fell, which was thrown on a filter in the usual way, and washed with alcohol and ether. When burned, it left 1·81 grains of metallic platinum, which are equivalent to 0·313 grains of caustic ammonia. This quantity was, therefore, contained in 126 cubic feet of air, at the temperature of 45° 63, and pressure of 29·58 inches. When reduced to 60° F. and 30 inches of pressure, the bulk of this air becomes 124·236 cubic feet. When converted into weights, reckoning 100 cubic inches of air equal to 31·0117 grains, this 124·236 cubic feet will amount to 6,850,296·19 grains, or 978·5 lbs. avoirdupois. 1000 lbs. of air will, therefore, contain 0·319 grains of caustic ammonia, or ·731 grains of carbonate of ammonia.[1]

In another experiment, the apparatus was arranged for the purpose of determining if any carbon or hydrogen existed in another form in the atmosphere, than as carbonic acid and water. The method consisted essentially (*see fig.*) in passing air through a tube filled with chloride of calcium (*b*), so as to deprive it of moisture, and enable the vapour in the air to be estimated; it then entered by a dipping tube into a solution of barytes (*c*), by means of which the carbonic acid was extracted; and for further security, it traversed a bulbed tube (*d*), also containing barytes. It was then dried by a chloride of calcium tube (*e*), and entered a tube filled with oxide of copper (*b*), heated to redness. If any hydrogen was present in the air in the form of a carbo-hydrogen compound, it was expected to become here oxidised and converted into water, which would be taken up by chloride of calcium (*g*). The air then dipped into a bottle (*h*) containing barytes solution, to take up the carbonic acid from the carbo-hydrogen compound, which would be oxidised by the oxide of copper. Thence it passed to the meter, where it was registered, and thence to the gas-holder, as already described. All the junctions of the tubes were rendered tight by means of caoutchouc and collodion.

The experiment was very satisfactory with regard to the carbonic acid in the atmosphere, as the precipitate of carbonate of barytes was apparent, and easily weighed; but no traces of water or carbonic acid could be detected in the chloride of calcium tube (*g*) beyond the oxide of copper; and in the barytes solution (*h*), although several feet of dry

[1] Since these experiments were made, Fresenius has published a set of experiments, in which he found the amount of ammonia in 1,000,000 grammes of air to be 0·098 grammes. The experiments above detailed make the amount of ammonia equal to ·045 gramme in 1,000,000 grammes of air—less than half the quantity found by Fresenius. This discrepancy may arise either from the two atmospheres being different, or from the rain which fell every day during the Glasgow experiments carrying down in solution a portion of ammonia to the earth.

air were passed through the ignited oxide of copper. A somewhat similar experiment was made by Boussingault, several years ago, upon the atmosphere of marshes. He came to the conclusion, that traces of carbon and hydrogen, in some form differing from carbonic acid and water, were diffused through the atmosphere over fens. If this were organic matter, it might have been derived from minute insects. But in the experiment now detailed this objection, it is conceived, was obviated in consequence of the air previously traversing two columns of fluid, which it was expected would detain any solid organic matter, whether vegetable or animal. The present experiment was made in the College Laboratory, the air being drawn from the street at a time when, in the neighbouring houses, persons were dying of cholera—in the centre of the city—a locality less liable to the diffusion of insects than the position examined by the French chemist. During the whole of the days when the experiment was carried on, a heavy mist existed, which, it is very probable, diminished greatly the amount of carbonic acid usually found in the air in dry weather. As the air, however, traversed three solutions, it is scarcely possible that any carbon could have escaped condensation.

The following table exhibits the results of the experiment:

TABLE XXXVI.

1849.	Cubic feet passed.	Thermometer. Degrees.	Barometer	Rain.
Jan. 27.	2·175	47·25	29·6 inches.	0·12 inches.
29.	0·55	39·75	29·91 ,,	0·30 ,,
30.	2·275	41·5	29·47 ,,	0·05 ,,
31.	. .	41	29·90 ,,	0·32 ,,
Feb. 1.	1·875	39·5	30·01 ,,	0·00 ,,
2.	1·45	43·75	30 ,,	0·08 ,,
3. } 6. }	1·75	45·5	30 ,,	0·00 ,, ,,
7.	0·1	. . .	. . . ,,	. . . ,,
27.	0·3	40·25	29·76 ,,	. . . ,,
	10·475	41·06	29·83	·87 inches.

The amount of carbonate of barytes derived from 10·475 cubic feet of common air, or 84·27 lbs., was 5·78 grains, which contained 1·297 grains of carbonic acid, or 2·78 cubic inches.

The following are the conclusions which seem deducible from the previous experiments:

1. That the incipient stage of cholera does not differ materially from the common forms of diarrhœa, inasmuch as its treatment is successfully managed by similar means; and this result may lead to the inquiry,—Does not the removal of the symptoms of the disease by narcotics, and, therefore, the retention of the fluids in the system, afford an argument against the idea of a morbid poison being the cause of cholera?

2. That in the second stage of cholera, a lymphatic fluid is diffused from the blood into the intestinal canal, corresponding exactly in chemical composition with that secreted or diffused through the serous membranes in hydrocele and hydrocephalus, and other forms of dropsy. Compared with healthy blood, it appears, that the salt which has diffused most largely into the intestines, is common salt, while the albumen of the blood possesses this power of transference generally in a very limited degree. The facts seem to show, that in this stage, instead of as in the natural state, the diffusive power of the mucous membrane being exerted from the intestines towards the blood, the reverse action occurs; thus pointing to a parallelism with purely physical phenomena. Conjoined with other characters, they supply an argument for the inquiry,—May not cholera be an *epidemic intestinal catarrh*, influenza being an *epidemic respiratory catarrh?*

3. In the third stage the lymphatic fluid ceases to be poured out from the blood. The bile is excreted, and the normal diffusion from the intestines to the blood resumes its action.

4. There is no evidence of the existence of any organic body in the atmosphere during the prevalence of cholera,

and hence the inquiry is suggested,—May not this and parallel diseases which are not contagious, such as ague, be principally due to meteorological and physical influences, acting on debilitated habits, and thus a distinction be established between them and contagious affections produced by morbid poisons, as typified by small-pox?