REPORTS
TO THE
SCIENTIFIC GRANTS COMMITTEE
OF THE
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REPORT ON CULTIVATION EXPERIMENTS WITH THE BACILLUS LEPRÆ.

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These experiments can be classified under the following three heads:

1. Experiments in nutrient media.
2. Experiments in living animal tissues.
3. Experiments in putrescent substances.

The results have been noted from day to day, and the three appended tables have been compiled from the record thus made. It will be seen that some of the experiments extend over nearly four years.

1. *Experiments in Nutrient Media.*—Sixty-five observations are tabulated. The tubes were kept at the ordinary tropical temperature, the average here being 79° F. for the twenty-four hours. Control experiments were made to test the sterility of the tubes. These, when kept for a considerable length of time without inoculation, showed contamination in a very few instances. The serum used was taken from lepers, as it was thought that bacilli might possibly grow more readily on it than on non-leprous serum.

The media used were:—Solid: (1) Blood serum; (2) serum from chest, abdomen, or tunica vaginalis; (3) serum mixed with 1 per cent. agar and gelatine; (4) serum and agar; (4) serum and gelatine. Liquid: (1) Ascitic fluid.

The materials used were: (1) Fragments of cutaneous tubercle; (2) tubercles from lung; (3) pieces of viscera; (4) pieces of femoral gland; (5) pieces of thickened nerve; (6) serum from blebs; (7) blood during acute leprosis; (8) fragments of cultures from the above.

The growths observed may be briefly described thus: (1) A whitish growth, like drops of oil paint; (2) a smooth, oily-looking, canary-yellow growth; (3) a salmon-coloured growth; (4) a faint white growth giving a green tinge to the serum. Besides these common mould was often accidentally present.

Under the microscope these growths showed the following: (1) Cocci; (2) micrococci; (3) streptococci; (4) large rods; (5) small rods. Nearly all these growths were tested with magenta and nitric acid. In four cases more or less stain was retained after the action of the acid.

In two of these cases the growth was yellow in colour, in one like drops of oil paint, and in one smooth, shining, and white, mixed with a salmon-coloured growth in one part. There was not, therefore, any constancy in the naked-eye appearances of the growths which retained some colour, nor did they differ from many other growths which did not retain colour. No reliance can, therefore, be placed on these four cases. Probably the acid was more diluted than usual, or did not gain access to all parts of the growth. Many of the fragments of tubercle were removed during acute leprosis, as it was thought that possibly the bacilli might grow more readily if planted at that time. No difference was, however, noted in the behaviour of these pieces; similar growths took place when the material was removed during a normal temperature.

In order to investigate the question of the nature of the tubercles in the lungs so often found in leprosy, I inoculated several tubes with these tubercles. I however did not succeed in getting any cultivation of the bacillus tuberculosis. This of course is only negative evidence, but so far as it goes it would tend to support Arning's view that the phthisis so common in leprosy is due to invasion of the lungs by the bacillus leprœ, and not by the bacillus tuberculosis. As a matter of fact, in the phthisical lungs of lepers which I have examined, I have found very few bacilli of any kind. This may, however, be due to the fact that pus or sputum was more often examined. It is well known that in rapid phthisis the number of bacilli does not keep pace with the destruction of tissue. A whole lung may be very rapidly excavated in leprosy.

Inoculations of guinea-pigs with portions of the growths gave negative results. Solutions of some of the cultures were also injected into the cutaneous tubercules of a leper; beyond superficial ulceration, no antagonistic effect was produced. The organisms found were practically identical with those found by Ballance and Shattock in their cultivation experiments with cancer and healthy tissues (*Pathological Society's Transactions*, vol. xxxviii, p. 438). As in their cases, I think that probably all the growths I observed were due to accidental contamination. This view is supported by the fact that cultivations from tubercles taken from the phthisical lung of a non-leprous subject resembled those from the phthisical lung of a leper. The bacillus tuberculosis was not satisfactorily seen. In some cases also no growth at all took place, the cutaneous tubercle remaining unchanged on the jelly. Most of the growths examined appeared to belong to the staphylococcus group.

This inquiry was already far advanced when Bordoni-Uffreduzzi announced his successful cultivation of the bacillus leprœ (*Zeitschrift für Hygiene*, October, 1887). I am not aware that his work has yet been confirmed.

2. *Experiments in Living Animal Tissues.*—An account of forty two inoculation experiments on animals has already been published (Journal, February 5th, 1887, p. 275). Twelve additional observations are now recorded in Table II. Some of these are the completion of experiments already published, and the others are inoculations of fresh animals or in new situations.

No. 1 is a case of considerable interest, from the length of time the dog was under observation. It was inoculated on the nape of the neck on April 5th, 1884, and was killed on December 16th, 1887—three and three-quarter years later. No trace whatever was found at the site of inoculation. Nodules were, however, found in the spleen and liver, which at first looked suspicious; but a further examination showed quantities of nematode worms in the hepatic veins, vena cava, right ventricle, and pulmonary artery. I sent these worms to Mr. Bland Sutton, and he has kindly written to tell me that they are probably filaria immitis, and that such worms frequently act as emboli. There is therefore, I think, little do ubt that the nodules in this dog were parasitic in origin, and not leprous. This view is supported by the fact that no bacilli were found in the nodules, nor indeed in any of the viscera.[1]

No. 23 is another animal which was a considerable time under observation. A piece of tubercle was introduced beneath the skin of a fowl on February 7th, 1885. The fowl died on March 4th, 1887, more than two years later, and at the site of inoculation a small nodule was found consisting of caseous *débris* and pigment surrounded by a capsule of false membrane. There was no infiltration of the tissues round the nodule, nor any evidence of leprous deposit elsewhere. A few badly stained bacilli were found in the *débris*, but none in the capsule, subcutaneous tissue, or viscera.

An interesting point arises here in connection with the nature of the phthisical lesions already referred to. Three fowls (including No. 23) were under observation for periods varying from ten months to over two years. During these periods they were all fed frequently with leprous material—namely, tubercles and pieces of viscera, including numerous phthisical lungs.

Now if these lung lesions were really caused by the bacillus tuberculosis, one would expect to find tubercular lesions in the fowls after such prolonged exposure. Mr. Bland Sutton, in an article on Asian tuberculosis in the *Philadelphia Journal of Comparative Medicine and Surgery* for October, 1886, says that fowls, pigeons, and ducks are exceptionally liable to this disease, and mentions the case of a python which died with tuberculosis of the liver after having been fed on the above birds.

Numerous instances are on record of other animals becoming tubercular after eating tubercular material. Thus Petit (*Journal de Médecine*, January 1st, 1888) relates the case of a cat which was constantly eating phthisical sputum, and eventually developed pulmonary tuberculosis. He has also seen two cases of tuberculosis transmitted to dogs by human beings. But the viscera of all my fowls were found quite healthy. This, therefore, is another argument, though not a very strong one, against the tubercular nature of the lung lesions in leprosy.

[1] April 9th, 1888, I have just received a letter from Dr. Thin, in which he says that both he and Mr. Watson Cheyne failed to find any leprosy bacilli in sections of spleen and liver.

TABLE 1.—*Experiments in Nutrient Media.*

No.	Date.	Name.	Age. M.	Age. F.	Country.	Duration of Leprosy.	Form of Leprosy.	Nutrient Medium.	Material Used.	Result.	Microscopic Appearances.	Remarks.
	1887.					Years.						
1	Feb. 16	Nathaniel Gale	13	—	Trinidad	3	T	Solid serum from chest and abdomen	Serum from blebs on legs	No growth	— —	During acute leprosis.
2	,,	,,	,,	—	,,	,,	,,	,, ,,	,, ,,	Slight white growth at edge of serum. Partial liquefaction	— —	,, ,,
3	,,	Robin Gobonia	18	—	Venezuela	9	T	,, ,,	Fragment of tubercle	Whitish yellow patch. Slight liquefaction	Very few bacilli (?) from original tubercle	
4	,,	,,	,,	—	,,	,,	,,	,, ,,	,, ,,	White flaky growth extending down into serum. Some liquefaction	Later examination (October 9th) showed only cocci *	
5	Mar. 2	William Allen	31	—	Trinidad	9	T	,, ,,	Fragment of tubercle from lung	Two yellow points and extensive white growth. Slight liquefaction	— —	
6	,,	,,	,,	—	,,	,,	,,	,, ,,	,, ,,	One yellow point and white film. More liquefaction	No evidence of leprosy or tubercle bacilli. Some large bacteria	
7	Mar. 4	John Henry	27	—	Nevis	5	M	,, ,,	Tubercle from lung	Yellow patch and white growth like mould	— —	
8	,,	,,	,,	—	,,	,,	,,	,, ,,	,, ,,	White growth like mould	Like No. 6	
9	Mar. 17	Cheekovee	36	—	India	11	A	,, ,,	Fragment of tubercular lung	Superficial growth like mould	— —	
10	,,	,,	,,	—	,,	,,	,,	,, ,,	,, ,,	Extensive yellow patch around tubercle and spreading down by pointed process into serum	Like No. 6	
11	Mar. 26	Growth from tube 3	—	—	—	—	—	,, ,,	Fragment of growth	Pale yellow growth mixed with brown. Slight liquefaction	— —	
12	,,	Growth from tube 4	—	—	—	—	—	,, ,,	,, ,,	Dirty-white oily-looking growth. Slight liquefaction	A few doubtful badly stained bacilli. Later examination (October 9th) showed only cocci *	
13	Mar. 28	Robin Gobonia	18	—	Venezuela	9	T	,, ,,	Fragment of tubercle	October 23rd; clear brown liquid with dirty sediment. Musty smell	Cocci, rods, granular *débris*, and disintegrated cells. Do not take magenta readily *	
14	,,	,,	,,	—	,,	,,	,,	,, ,,	,, ,,	,, ,,	,, ,,	
15	April 14	Laratee	—	52	India	5	M	Liquid ascitic serum	Fragment of lung	September 16th; no change. Fragment lying at bottom of tube with clear serum above	Quantities of cocci taking magenta well *	
16	,,	,,	—	,,	,,	,,	,,	,, ,,	,, ,,	January 10th, 1888; no change. Fragment lying at bottom of tube with clear serum above	Numerous cocci and a few rods *	
17	,,	,,	—	,,	,,	,,	,,	,, ,,	Fragment of femoral gland	September 16th, 1887; no change. Fragment lying at bottom of tube	Masses of cocci and large swollen cells with bacilli in interior *	Possibly the original bacilli swollen by maceration.
18	April 22	Robin Gobonia	18	—	Venezuela	9	T	,, ,,	Fragment of tubercle	January 10th, 1888; no putrid smell. Tubercle much swollen, covered with thin film (bacillus subtilis ?) upper liquid clear	Sediment showed highly refracting cocci and rods. Take magenta well *	
19	May 14	Tube 6	—	—	—	—	—	Solid serum	Fragment of growth	Yellow growth in groove of wire. Progressive liquefaction	Spores and rods *	
20	,,	Tube 8	—	—	—	—	—	,,	,, ,,	Thick yellow growth on surface and a few points of growth low down in solid. Considerable liquefaction	,, ,,	
21	,,	Tube 10	—	—	—	—	—	,,	,, ,,	Bright yellow growth. Mould. Liquefaction	Swarms of spores and bacteria *	
22	May 16	Robin Gobonia	18	—	Venezuela	9	T	Blood serum	Fragment of tubercle	Growth like patch of brown oil paint spreading from tubercle. Round yellow growth in centre of serum	In growth near tubercle cocci and large and small rods. In growth in centre, cocci *	
23	May 17	Tube 12	—	—	—	—	—	Solid serum	Fragment of growth	Yellow growth and partial liquefaction. Some putrid odour	Cocci and long and short rods *	Third generation.
24	May 23	Raturan	68	—	India	10	M	,,	Fragment of tubercle	White growth on tubercle and on serum. Serum liquefied, putrid	Numerous cocci and some rods *	
25	,,	,,	,,	—	,,	,,	,,	,,	,, ,,	,, ,,	,, ,,	
26	June 1	Eugenie Lewis	—	25	Trinidad	4	T	,,	,, ,,	October 23rd, 1887; clear brown liquid. Dirty sediment. Common mould floating on surface. Musty smell	— —	Soon after acute outbreak.
27	,,	Elvira Archibald	—	8	,,	1	M	,,	,, ,,	,, ,,	A few cocci *	
28	June 6	Julian Brown	20	—	,,	6	M	Partly solid serum	,,	,, ,,	Numerous cocci, also large cells and some branching mycelium *	
29	June 17	Janetha Thompson	—	18	Barbadoes	1	T	Serum and gelatine		November 12th, 1887; Viscid yellowish mass	Swarms of cocci and short thick rods. Do not take magenta readily *	
30	,,	Robin Gobonia	18	—	Venezuela	9	T	,, ,,	,,	Liquefaction. No growth on surface. Whitish sediment	— —	
31	June 22	,,	,,	—	,,	,,	,,	Serum and agar-agar		Small white growth like powdered flour. No liquefaction.	Oval shining cocci and short rods *	

32	June 22	John Saunders	21	—	Trinidad	4	M	Blood serum	Fragment of tubercle	Smooth shining white growth ¼ by ½ inch salmon-coloured at one part. Serum translucent beyond growth	Quantities of cocci and large and small bacilli. Take magenta readily, and numerous spores and short thick rods resist action of nitric acid
33	July 3	Tube 32	—	—	—	—	—	Solid hydrocele fluid	Fragment of growth	Yellow film on surface, much brighter in one place. Translucency in line of needle. No liquefaction	Swarms of cocci and short rods. Take magenta readily. Some retained after nitric acid
34	July 8	Bansee	40	—	India	3	T	Blood serum	Fragment of tubercle and some blood	Small white beads spreading like drops of oil paint on serum. Eventually they dried up	Densely packed spores. In some a faint colour after action of nitric acid
35	July 11	,,	,,	—	,,	,,	,,	Solid hydrocele fluid	Fluid from bleb	Thin bright yellow growth. No liquefaction	Swarms of cocci and rods. Some retain colour after nitric acid
36	July 12	Tube 34	—	—	—	—	—	,, ,,	Fragment of growth	Thick white film like mould. No liquefaction	Spores, granular matter and mycelium *
37	July 15	Bansee	40	—	India	3	T	Nearly solid serum	Fragment of tubercle	White film. Liquefaction	Cocci and long rods (? bacillus subtilis). After magenta and nitric acid, patches of pink are seen with clear spaces occupied by unstained bacilli
38	July 19	Eleanor Hudson	—	17	Nevis	3	T	Solid serum	,, ,,	Liquefaction of serum. Thick white film on surface. Fragment of tubercle unchanged	Closely packed round and oval cocci, also some short thick rods. Take magenta readily * January 17th, 1888; some cells retain magenta after nitric acid, but bacilli not seen (? fragments of original tubercle)
39	July 20	Robin Gobonia	18	—	Venezuela	9	T	,,	,, ,,	Thick creamy growth on surface. No liquefaction. Musty smell.	Quantities of cocci; singly and in clusters and rods
40	Sept. 12	Janetha Thompson	—	18	Barbadoes	1	T	Serum and agar-agar	,, ,,	Slight liquefaction. No apparent growth	A few small cocci. Some arranged in streptococci *
41	Sept. 19	Egbert Swain	20	—	,,	7	M	,, ,,	Blood	October 23rd, 1887; serum putrid, liquid. Film floating on surface. Considerable sediment	Numerous cocci; beaded rods of various lengths, some showing vigorous curling movements *
42	Sept. 20	Robin Gobonia	18	—	Venezuela	9	T	Serum and 1 % agar-agar and gelatine	Tubercle and blood	Smooth white oily growth. No liquefaction	— —
43	,,	Egbert Swain	20	—	Barbadoes	7	M	,, ,,	Blood	Mould, no liquefaction. Later yellowish growth with slight liquefaction	Quantities of branching mycelium. Later cocci *
44	Sept. 30	Assee	39	—	China	2	M	,, ,,	Fragment of tubercle	Surface of serum covered with thick smooth white growth	Swarms of cocci and a few beaded bacilli*
45	Oct. 3	William Green	11	—	Trinidad	5	T	,, ,,	Fragment of yaw tubercle	Smooth white oily growth round tubercle. Yellow patches in places. Mould at another part	Swarms of cocci *
46	Oct. 9	Tube 4	—	—	—	—	—	,, ,,	Fragment of deposit	Growth dirty white patches like drops of oil	Numerous small cocci and large rods *
47	,,	Tube 11	—	—	—	—	—	,, ,,	Fragment of growth	Jan. 25, 1888. Faint white growth on surface of serum. Olive green tinge of serum. No liquefaction	Numerous cocci *
48	,,	Tube 37	—	—	—	—	—	,, ,,	,, ,,	Jan. 25, 1888. Dirty white growth at edges and on surface of serum No liquefaction	Numerous cocci and long and short rods *
49	Oct. 16	Tube 45	—	—	—	—	—	,, ,,	,, ,,	Yellow growth in groove of wire. Surrounding this, flat white patches like oil paint. Outside this, pale yellow growth. Slight liquefaction Later. Red specks like cayenne pepper appeared on surface	Quantities of shining oval cocci: a few good sized bacilli. The bacilli take magenta readily, but not the cocci *
50	,,	Tube 44	—	—	—	—	—	,, ,,	,, ,,	Flat white patches like oil paint. No liquefaction	Numerous spores and rods. Many of the later with active curling movements
51	Nov. 12	Tube 29	—	—	—	—	—	,, ,,	,, ,,	Opaque white growth scattered on surface. Slight liquefaction	Swarms of refracting round and oval cocci and some short rods *
52	,,	Bansee	40	—	India	3	T	,, ,,	Fragment of lung with tubercle	Serum depressed and group of small whitish and yellowish patches around tubercle of lung	Quantities of short rods about the size of bacilli tuberculosis. Take magenta readily *
53	,,	,,	,,	—	,,	,,	,,	,, ,,	Fragment of spleen with tubercle	Flat white growth around tubercle of spleen. Afterwards changing to bright yellow. Tubercle remains moist	Numerous cocci. Take magenta *
54	,,	,,	,,	—	,,	,,	,,	,, ,,	Fragment of liver	Flat white growth on surface. Green tinge of serum (? bile). No liquefaction	Cocci and various sized rods, Do not take magenta readily *
55	,,	Guinea Pig LXVI	—	—	—	—	—	,, ,,	Piece of skin at site of inoculation	Pale yellow growth like oil paint. No liquefaction Later. Salmon-coloured pellicle. Tube putrid	Numerous cocci * Later. Numerous small rods and cocci. Magenta stains deeply *
56	Nov. 18	Egbert Swain	20	—	Barbadoes	7	M	,, ,,	Piece of cutaneous tubercle	Jan. 8, 1888. Tubercle moist, unchanged. Serum unchanged. No growth	— —
57	Nov. 23	Ophelia Mackenzie	—	17	Trinidad	4	M	,, ,,	,, ,,	Salmon-coloured growth on surface	Swarms of cocci and some rods. Take magenta fairly fairly well *

* Means all colour of magenta destroyed by nitric acid.

TABLE I.—*Experiments in Nutrient Media. (Continued.)*

No.	Date.	Name.	Age. M.	Age. F.	Country.	Duration of Leprosy.	Form of Leprosy.	Nutrient Medium.	Material Used.	Result.	Microscopic Appearances.	Remarks.
58	Nov. 23	Tube 52	—	—	—	—	—	Serum and 1% agar-agar and gelatine	Fragment of growth	Green tinge. White oily growth along needle track. Later. Faint scanty growth towards edges of surface	Strongly refracting. Short thick rods and cocci. Do not take magenta readily *	
59	,,	Tube 53	—	—	—	—	—	,, ,,	,, ,,	,, ,, ,,	,, ,, ,,	
60	,,	Tube 54	—	—	—	—	—	,, ,,	,, ,,	,, ,, ,,	,, ,, ,,	
61	Nov. 24	Tube 55	—	—	—	—	—	,, ,,	,, ,,	Pale yellow growth and some liquefaction and putridity. Later. Rich salmon pellicle	Small rods and cocci. Stain deeply with magenta *	
62	Nov. 28	Robin Gobonia	18	—	Venezuela	9	T	,, ,,	Piece of tubercle	Tubercle has partly sunk into serum. Round it and on it are little round shining white masses, tending to coalesce. Later. Mixture of dirty white, salmon and canary yellow	Swarms of rods and cocci, also streptococci and leptothrix of various sizes. Do not take magenta readily *	Guinea pig LXVIII inoculated with some of this growth on Dec. 4. No result. Was killed on Feb. 13, 1888. Viscera healthy.
63	,,	,,	,,	—	,,	,,	,,	,, ,,	,, ,,	,, ,, ,,	,, ,, ,,	Guinea pig LXVII inoculated with some of this growth on Dec. 8. No result. Was killed on Feb. 13, 1888. Viscera healthy.
64	Dec. 9	Azariah Abraham	18	—	Trinidad	8	T	,, ,,	Piece of thickened nerve	Thick salmon-coloured growth covering surface of serum and extending ⅛ to ¼ in. down sides. Slight ammoniacal smell	Swarms of small rods and cocci (smaller than usual). Stain very deeply with magenta. After prolonged staining nitric acid destroys all colour	
65	,,	,,	,,	—	,,	,,	,,	,, ,,	,, ,,	,, ,, ,,	,, ,, ,,	

TABLE III.—*Experiments in Putrescent Substances.*

No.	Date of Last Examination.	Name.	Age. M	Age. F	Country.	Duration of Leprosy.	Form of Leprosy.	Material and How Used.	Result.	Remarks.
						Years				
1	May 11, 1887	Bheekha	41	—	India	12	A	Dried blood kept for five months	No bacilli	
2	May 14, 1887	Robin Gobonia	18	—	Venezuela	9	T	Fragment of tubercle from R. G. put into stoppered bottle with ascitic fluid from L. C, and allowed to get putrid	No leprosy bacilli	
3	June 4, 1887	,,	,,	—	,,	,,	,,	,, ,,	Plenty of bacillus subtilis, no leprosy bacillus	Put in April 22nd.
4	June 2, 1887	Leonine Collins	—	12	Trinidad	3	T	Putrid serum from chest and abdomen	No bacillus in either	
5	,,	Joseph Scott	21	—	,,	17	M	Putrid blood twenty-four days old	Swarms of bacillus subtilis, no leprosy bacillus	
6	Nov. 26, 1887	Robin Gobonia	18	—	Venezuela	9	T	Piece of tubercle put in putrid serum from L. C. in bottle	Numerous short rods and cocci *	,, June 24th.
7	Jan. 3, 1888	,,	,,	—	,,	,,	,,	Piece of tubercle put in putrid blood from J. A.	Large and small cocci, some in chains. Thick bacilli*	,, ,,
8	Nov. 8, 1887	Joseph Scott	21	—	Trinidad	17	M	Enlarged femoral glands, thickened tubercular skin, and tissues around larynx buried	No trace of tissue (ants had been excavating). Three specimens of earth stained. Some large bacilli found, but no leprosy bacilli	Buried July 28th.
9	Aug. 19, 1887	Eugenie Lewis	—	25	,,	4	T	Piece of tubercle put in putrid blood and serum from heart and pericardium of J. S. (18 days)	Clear fluid with thick *débris* of broken tubercle, etc., at bottom. Cocci and short thick rods in clear fluid and sediment. No leprosy bacilli	
10	Oct. 20, 1887	Michel Cheli	31	—	,,	15	M	Enlarged femoral glands and pieces of other tissues buried	A little slimy *débris* left with faint smell. Examined (1) portion of tissue mixed with earth (2) one inch laterally (3) earth six inches laterally (4) earth from surface of ground. In (1) and (2) a few deeply stained cells and rods and numerous unstained rods. In (3) and (4) a good many more or less stained rods, no stained cells. Examined again December 4th. Earth-worms and eggs found. Two specimens of earth and fluid from embryo-worm stained. Nnmerous dark rods, but no undoubted leprosy bacilli	,, September 25th.
11	Nov. 24, 1888	Deshudsingh	32	—	India	5	,,	Piece of tubercle in putrid serum from leg of G.	Opaque white putrid liquid. Swarms of putrefactive bacteria, but no leprosy bacilli	Put in November 11th.
12	Mar. 16, 1888	Azariah Abraham	18	—	Trinidad	8	T	Hand and two kidneys buried	Bones of hand found but no remains of kidneys. No bacilli found at site of hand or kidneys, or on surface of ground above hand or kidneys, or six inches laterally from hand	Buried December 8th.

* Means all colour of magenta destroyed by nitric acid.

TABLE II.—*Experiments in Living Animal Tissues.*

No.	Animal Inoculated.	Site of Inoculation.	Source of Material.	Form of Leprosy.	Date of Inoculation	Date of Last Examination.	Result.	Remarks.
1	Dog	Nape of neck	Scrapings from ulcers of N. D. and J. G.	T M	April 5, 1884	Dec. 16, 1887	No local thickening. Nodule about size of pea in anterior border of spleen. On upper surface of liver a dense, slightly raised mass about one inch in diameter projecting some distance into liver. Not very well defined but paler than surrounding tissue. Distended capillary on upper surface. Mesenteric glands perhaps a little enlarged. Magenta failed to show bacilli in liver, spleen, kidney, heart, or mesenteric gland	Numerous næmatode worms 3 to 4 inches long in hepatic veins, vena cava, right ventricle, and pulmonary artery.
23	Fowl	Beneath skin of back, also under left wing	Pieces of tubercle, J. J.	T	Feb. 7, 1885	Mar. 4, 1887	Small nodule about ½ × ½ inch under right wing. Found on section to consist of caseous *débris* and pigment. Firm capsule of false membrane. No infiltration of tissues beyond capsule. Magenta showed a few badly stained bacilli in caseous *débris*. Viscera healthy. No bacilli in liver, lung, or gizzard. None in capsule or tissues near tubercle	This bird was also fed with numerous tubercles and portions of viscera obtained *post mortem*.
43	Cat	Abdominal cavity	Two pieces of tubercle R. G.	,,	Dec. 13, 1886	June 24, 1887	Small brownish yellow nodule about ¼ inch long was found attached loosely to mesentery. Cut easily like cheese, centre darker. A few bacilli found in it. No trace of cicatrix found in abdominal wall or peritoneum. Viscera healthy. Magenta showed no bacilli in liver, spleen, kidney, lung, pancreas, ovary, or placenta	
44	,,	Anterior chamber	Piece of tubercle, R. G.	,,	Feb. 4, 1887	Jan. 28, 1888	Tubercle in left pupil, adherent to iris and lying on lens. White lymph on surface and surrounded by rim of injection. Small vessels running across iris to tubercle and corneal opacity over it. Black pigment in cicatrix. Whole iris yellow, has lost its gloss. Capillaries injected and lymph at margin of pupil. Slight scurfiness above left eye, but no nodule there now. Some corneal opacity in right eye	Eye in exactly the same state as on September 26th.
45	,,	,,	,, ,,	,,	Feb. 9, 1887	,,	Patch of pigment and white corneal opacity about ½ × ½ inch around cicatrix. Slight bulging of cicatrix. Iris rather darker in colour than right. Points of opacity on cornea. Five translucent nodules about size of pins' heads over sclerotic. Magenta showed no bacilli in juice from these. Threads of lymph running up from iris to cicatrix. Deposit of lymph on lower part of iris, dilated vessel and some pigment on surface of iris. Tubercle appears to have escaped	
46	Macaw	Beneath left wing ,, right ,,	,, ,, E. N.	,, ,,	June 6, 1887 July 4, 1887	Jan. 27, 1888	No sign of tubercles, not even of scars. Incisions gaped and tubercles escaped after a few days. A few bacilli found in scab twelve days after inoculation	This bird was also vaccinated with lymph from D (mixed) on August 9th, 1887.
47	Kitten	Anterior chamber after iridectomy	,, E. L.	,,	Aug. 1, 1887	Jan. 28, 1888	Mass of pigment in cicatrix and iris dragged forward and adherent here. Tubercle has escaped. Cornea clear. No evidence of growth on iris. Slight yellow tinge at upper and lower margin of pupil, otherwise iris is same colour as right.	
48	,,	,,	,, ,,	,,	,,	,,	Pigment in cicatrix, iris adherent. Tubercle apparently has escaped. No difference in colour of iris. Small point of opacity over centre of cornea	
49	,,	Anterior chamber	,, D	M	Oct. 17, 1887	,,	Iris adherent to cicatrix. Injection and opacity of cornea round. No change of colour of iris. Tubercle apparently has escaped	
50	,,	Abdominal cavity	,, ,,	,,	,,	Oct. 28, 1887	Incision closed by lymph. Intestine adherent. Acute peritonitis. Tubercle not found. Viscera healthy. A few doubtful bacilli in peritoneal lymph, none in lung	
51	Guinea-pig	Nape of neck	,, F. L.	T	Oct. 29, 1887	Jan. 27, 1888	Hair grown. Scar visible but no thickening. Numerous leprosy bacilli in pus from incision four days after inoculation	Tubercle removed during acute leprosis, temperature 103°. Died February 13th, 1888, viscera healthy.

In Experiment 43 a piece of tubercle was introduced into the abdominal cavity of a cat. This incision healed readily, and the cat was killed six months later. A small nodule was found loosely attached to the mesentery; it was caseous on section and contained a few bacilli. The viscera were healthy and contained no bacilli. The result here resembled that obtained beneath the skin of the fowl.

A kitten which had been similarly inoculated in the abdominal cavity died eleven days later with acute peritonitis. The tubercle was not found, but a few doubtful bacilli were found in the peritoneal lymph. Two cats and three kittens were inoculated with pieces of tubercle in their anterior chambers. In four the tubercles apparently escaped and the incisions healed, leaving only some opacity and pigment round. In the fifth the tubercle remained over the pupil, resting on the lens, and adherent to the iris. General iritis was set up, and the tubercle became coated with yellow lymph.

At the last examination, on January 28th, 1888, the eye was in exactly the same state as on September 26th, 1887, four months before.

On October 17th, a small desquamatory nodule was found over the eyebrow above the inoculated eye. Some juice from this nodule was sent home and submitted to Dr. Thin and Mr. Watson Cheyne, who kindly examined it, but failed to find any leprosy bacilli in the specimen sent. By January 28th, 1888, the nodule had disappeared, leaving only a slight scurfiness. It would seem probable, therefore, that this nodule was only accidental. The results of inoculation in the anterior chamber agree with those of Dr. Thin (*Impfversuche mit Lepragewebe auf Thiere*, 1886). I have been told that a parrot has been known to become leprous at the asylum here. I, therefore, inoculated a macaw beneath each wing. Six months later no sign of tubercles, nor even of scars, was found.

A guinea-pig was inoculated with a piece of tubercle removed during an acute outbreak, the temperature being 103°. It was thought that possibly the bacilli might grow better if removed at this time. The incision suppurated, and numerous leprosy bacilli were found in the pus four days after inoculation. The guinea-pig died three and a half months later; no trace of the tubercle was found near the cicatrix, and the viscera were healthy.

I have now under observation at the asylum thirty selected anæsthetic lepers. I introduced in each beneath the skin of the forearm, a few months ago, a piece of cutaneous tubercle from a tuberculated leper, the incision being afterwards sutured. I am watching carefully for any growth of tubercle, but none has yet taken place. Hansen has tried similar transplantation on man without result (Bidenkap, *Lectures on Lepra*, 1886, p. 61). So far, then, I can record no growth of the bacillus lepræ when planted in living animal tissues.

3. *Experiments in Putrescent Substances.*—Arning was, I believe, the first to investigate the question of the behaviour of the bacillus lepræ in putrid substances (*Report on Leprosy in Hawaii*, 1886, Appendix, p. 53). He found that when leprous tissue was set aside, and the growth of the larger fungi excluded, the bacillus lepræ held its own against other micro-organisms, and, further, that it was met with so abundantly, and so laden with spores as to suggest actual increase. The bacillus was also found in large numbers on examining the corpse of a tuberculated leper which had been buried for nearly three months. Dr. Arning acknowledged that he could not definitely determine whether these bacilli were still alive and capable of reproducing the disease; but, from their microscopical appearance, he felt confident that such was the case. As he remarks, the question is one of immense importance with reference to public health. If it is possible for the bacillus to multiply in the bodies of dead lepers, it would no doubt be safer for all such bodies to be burnt, even though it is not yet actually proved that the bacillus is the cause of leprosy.

In connection with this subject I have made twelve observations, which are described in Table III. I have examined the question in three ways: 1. By keeping blood or serous effusion from lepers in closed vessels or between glasses. 2. By keeping pieces of cutaneous tubercle in putrid blood or serum from lepers, in closed bottles or test tubes. 3. By burying leprous tissues.

The first method is perhaps of less value from the fact that I have never succeeded in finding leprosy bacilli in the blood or serous effusions of lepers. Köbner has, however, described bacilli in the blood, and it is at least possible that spores may be present in the fluids of the body, which may germinate outside the body under certain conditions.

In this and in the second series of experiments I found no evidence whatever of leprosy bacilli when the material was examined at various intervals. The putrefactive bacteria seemed to have it all their own way. Of course, it is possible that the leprosy bacilli originally present in the fragments of tubercle may still have been in the fluid, though they may not happen to have been taken up in the pipette for examination. But even when the *débris* at the bottom of the vessel was specially examined, I failed to find any bacilli which retained magenta. It seems therefore fair to conclude that there was certainly no increase of bacilli in these putrid fluids, and that very possibly the original bacilli became more or less destroyed or altered by maceration. This is in accord with what I have observed when leprous tubercles have been allowed to remain for prolonged periods beneath the skin of fowls as described earlier in this report. Only a few badly stained bacilli were found amongst the caseous *débris*; the bulk of the bacilli seemed to have been destroyed with the tubercle.

Similarly in Observation 17 of Table I, in which a fragment of femoral gland from a mixed leper was kept in sterilised ascitic fluid. Five months later, the fragment was still lying at the bottom of the test tube; there was no putrefaction, and microscopic examination showed large swollen cells with bacilli in their interior. These, however, did not retain magenta after the action of nitric acid. It would thus appear possible that bacilli after prolonged maceration may become so changed as not to respond to the ordinary colour test. This may partly explain the apparent absence of the original bacilli in putrid fluids.

To test the third point—the behaviour of the bacillus lepræ when buried—various parts of three lepers, two mixed and one tuberculated, were buried about six inches below the surface of the earth. The remains were examined after periods of one, two and a half, three, and four months. In the first case the experiment was practically vitiated, for it was found that parasol ants had been excavating where the tissue was buried, with the result of disturbing its relations to surrounding parts. Three examinations of the earth failed to show leprosy bacilli.

In the next case, after a month, a little slimy *débris* was found with faint smell. Specimens of this material and of the earth, one inch laterally, six inches laterally, and from the surface of the ground, were examined. After the action of magenta and nitric acid, deeply stained cells and rods were found in the *débris* and its immediate neighbourhood, whilst, further off, a good many more or less stained rods were found. I am, however, very doubtful whether these were leprosy bacilli; they looked too large. Possibly their retaining the stain after the action of the nitric acid was due to an admixture of earth, which protected them to some extent from the action of the acid.

Another examination, six weeks later, gave a similar result. Earth worms and their eggs were also found, and fluid from the embryo worm in the egg was stained, as it was thought that possibly these worms might be instrumental in bringing up bacilli to the surface, as was found by Pasteur when examining the buried carcases of animals dying of anthrax. No undoubted bacilli were found in any case, only the dark rods above mentioned.

In the third case, after four months, the bones of the tuberculated hand were dug up; but examination of the earth, at various distances from the bones, failed to show any bacilli at all.

I cannot, therefore, agree with Dr. Arning as to the power of resistance of leprosy bacilli to putrefaction; much less have my observations convinced me that they have any power of germinating under such circumstances.

Conclusion.—In concluding this report, I can only regard it as a very meagre contribution to our knowledge of the life history of the bacillus lepræ. An inquiry of this kind is practically endless, so varied are the conditions of temperature, time, nutrient medium, living animal tissue or putrescent substance, and so many are the observations necessary to avoid or lessen the risk of errors of experiment.

Such as they are, however, my conclusions are the result of four years' work, and I here summarise them:

1. At a tropical temperature and on the ordinary nutrient media, I have failed to grow the bacillus lepræ.

2. In all animals yet examined, I have failed to find any local growth or general dissemination of the bacillus after inoculation, whether beneath the skin, in the abdominal cavity, or in the anterior chamber. Feeding with leprous tissues has also given negative results.

3. I have found no growth of the bacillus lepræ when placed in putrid fluids or buried in the earth.

REPORT ON SOME OF THE MOTOR FUNCTIONS OF CERTAIN CRANIAL NERVES (V, VII, IX, X, XI, XII), AND OF THE THREE FIRST CERVICAL NERVES, IN THE MONKEY[1]

(*Macacus sinicus*).

By CHARLES E. BEEVOR, M.D., F.R.C.P.,
AND
VICTOR HORSLEY, B.S., F.R.S.
(From the Laboratory of the Brown Institution.)

In the course of an investigation into the cortical representation of the muscles of the mouth and throat we have experienced considerable difficulty in describing correctly the movements of these parts, especially when there was any question of bilateral action occurring. On referring to textbooks we failed to find any solution of this difficulty, and we therefore determined to make a few observations of the movements evoked by stimulating the several cranial nerves supplying this region in the monkey[2] so as to have a definite basis whereon to ground our observations of the movements obtained by stimulating the cortex.

In the course of this work[3] we have observed several facts which do not harmonise with the views hitherto generally received.

Method of Investigation.—The foregoing summary of our experiments is based almost entirely upon the results obtained by exciting the respective nerves at the base of the cranial cavity after separating them from the bulb. We have also stimulated the nerves outside the skull in the neck both before and after division. In either case the animal was narcotised with ether.

(1.) For the exposure of the nerves at the base of the cranial cavity it was found possible to rapidly remove a cerebral hemisphere, clamping the carotid and other arteries, then to divide the tentorium and to remove the major part of the cerebellar hemisphere of the same side, so as to admit of prolonged and numerous observations before the animal died. In all we have done eight experiments, and in every case we have operated on the same kind of monkey, that is, *Macacus sinicus*.

(2.) For the exposure of the nerves outside the skull we found it easy to lay bare the upper cervical nerves and those of the

[1] The expenses of the research have been defrayed by the British Medical Association.
[2] Previous observers having employed animals of lower orders.
[3] Full publication is given in the *Proc. Roy. Soc.*, 1888.

cranial division in the anterior triangle by turning forward a triangular flap of skin, ligaturing and removing the external jugular vein and dividing and turning aside completely the sterno-mastoid muscle. Finally, the parotid gland and digastric muscle (posterior belly) were drawn up with hooks, the head being turned to the opposite side.

The chorda tympani was readily exposed without injury in the tympanic cavity, *before* the dissection of the triangle, by cutting away the posterior wall of the external auditory meatus and the posterior half of the tympanic ring. The facial nerve was subsequently exposed in the stylo-mastoid foramen and aqueduct.

The nerves were in each case carefully raised up from their position and stimulated in the air by the faradic current through fine platinum electrodes, the area of the operation having been carefully dried. The current employed was from the secondary coil of an ordinary Du Bois-Reymond inductorium, supplied by a 1 litre bichromatic cell. The experiment was carefully begun with the secondary coil at a distance of 30 centimètres from the primary, this interval being very rarely diminished to more than 15 centimètres (zero being of course the point where the secondary coil completely overlaps the primary).

Further Observations respecting the Examination of each Nerve.—*A.* Cranial Division.

Fifth Nerve.—Excitation of the motor root of the trigeminus evoked powerful closure of the jaws, and although the muscles of one side only were in action, the teeth were approximated without any lateral deviation of the lower jaw.

Seventh Nerve.—The motor distribution of the facial nerve has, for the most part, been well known for some time. However, we consider that unfortunately a very fundamental error respecting this distribution has crept into the text-books, it being supported by one anatomical authority following another, and, moreover, having been accepted by clinicians as an important aid in the differential diagnosis of facial paralysis. We refer to the supposed supply of motor fibres from the facial to the levator palati through the superficial petrosal nerve. This idea,[4] upon which so much stress has been laid, is entirely hypothetical, as might have been shown at any time by stimulating the facial nerve in the skull, and observing the soft palate. We have found that stimulation of the peripheral end of the divided facial nerve in the internal auditory meatus failed to cause, even with most powerful currents, the slightest movement of the soft palate, although the face was thrown into violent spasm. The true motor nerve supply of the levator palati is, according to our observations, the eleventh nerve (*vide infra*).

IXth Nerve. Glosso-pharyngeal.—In exciting this nerve, in addition to the movements of the pharynx, which we attribute to the contraction of the stylo-pharyngeus, and possibly to the middle constrictor of the pharynx, we have observed certain movements of the palate, as follows:—(1.) Stimulation of the nerve while beneath the stylo-hyoid ligament and uncut, gave, in two instances, elevation of the palate on the same side, and in one instance on both sides. We suppose that everyone will consider with us this movement to be reflex in origin, but we must add (2) that in one case we saw elevation of the palate to the same side when exciting the peripheral end of the cut nerve. In this latter case, perhaps, the result may be explained by the close neighbourhood of the pharyngeal plexus and the possible escape of current thereto, and, under any circumstances, this is but a single exceptional observation, so that we lay no stress upon it. Finally, we never saw movement of the soft palate when the glosso-pharyngeal nerve was stimulated within the cranial cavity.

Tenth Nerve. Vagus.—In stimulating the uncut nerve outside the skull, below the level of its junction with the hypoglossal, rhythmical movements of swallowing were produced, which occurred at the rate of twenty-five times in thirty-five seconds. In one observation all the constrictors of the pharynx were thrown into action, when the peripheral end of the cut nerve was stimulated outside the skull. The rhythmical movements of swallowing obtained by stimulating this nerve must form, of course, the simple reflex, the stimulus acting on the nerve in the centripetal direction, and that this was the case is proved by the fact that no movement was obtained when the peripheral end of the cut nerve was stimulated inside the skull. The superior laryngeal branch, on being stimulated, gave rhythmical movements of swallowing at the rate of seventeen times in fifteen seconds; but when the nerve was cut and its peripheral end stimulated, only very slight movement was produced in the larynx, evidently by contraction of the crico-thyroid muscle.

Eleventh Nerve. Accessory to Vagus.—In discussing the motor functions of the seventh nerve, we stated that the hitherto received idea of the soft palate being supplied by the facial nerve was, according to our observations, entirely erroneous. We find that the levator palati is supplied entirely by the eleventh nerve.[5] When the peripheral end of the cut nerve was stimulated inside the skull, elevation of the soft palate on the same side was invariably seen. The path by which the fibres from this nerve reach the palate is probably through the upper branch of the pharyngeal plexus.

Twelfth Nerve. Hypoglossal.—When the entire nerve was excited outside the skull, just below the point where it is joined by the first cervical nerve, the tongue was flattened posteriorly on the same side, and the tip protruded also on the same side, while in no case was there any heaping up of the tongue. At the same time the depressors of the hyoid bone were thrown into action, and in some cases this dragging downwards of the hyoid completely prevented the tongue from being protruded. The movements described above were repeated without alteration when the peripheral end of the cut nerve was excited at the same place. It must be particularly noted that the movements of the tongue were purely unilateral, and this was proved to be the case beyond doubt by two experiments, in which the tongue was divided longitudinally in the middle line to the hyoid bone, when the movements were seen to be entirely confined to the side stimulated. When the cut nerve was excited within the skull, a different result was obtained, the tongue was flattened behind, and protruded towards the same side, but there was no action in the depressors of the hyoid. It has always been held that the depressors of the hyoid bone receive their motor nerve supply from the hypoglossal through the descendens noni; but, as will be shown further on, according to our observation, these muscles are supplied by the first and second cervical nerves, and it is only when the hypoglossal is stimulated below the point where it is joined by the branch from the first cervical nerve, that any movement is produced in the depressors of the hyoid.

B. Spinal Division.

Our observations of the motor functions of the first three cervical nerves, as regards their influence on the hyodean muscles, have been made when the nerves have been excited—(*a.*) In the spinal canal. (*b.*) In the neck immediately upon their exit from between the vertebral transverse processes. The nerves in the spinal canal were separated from the spinal cord and thoroughly dried, the efficacy of the precautions taken against spread being evidenced by the difference in result obtained by exciting each root. The effects obtained by the methods *a* and *b* were identical.

First Cervical Nerve. Branch of Union with the Hypoglossal.—In the description of the twelfth cranial nerve, we have stated as the result of our experiments that the depressors of the hyoid bone are not thrown into action when this nerve is stimulated within the skull. On carefully dissecting out the branch from the first cervical nerve to the hypoglossal, we find that excitation of it evokes no movement in the tongue, but the depressors of the hyoid bone are strongly contracted. Of these muscles, the sterno-hyoid and sterno-thyroid were always especially affected, while the omo-hyoid was less frequently seen to contract, and in some cases not at all. In the cases where this muscle contracted, in one experiment the anterior belly alone acted, and when both bellies contracted, the movement in the anterior was in excess of the posterior.

Second Cervical. Branch to the Descendens Noni.—On stimulating this nerve, the depressors of the hyoid were thrown into action, but the muscles involved were not affected in the same way as was the case with the first cervical nerve. The muscle which was most constantly set in action by excitation of the second cervical nerve was the omo-hyoid, and especially its posterior belly. The sterno-hyoid and sterno-thyroid also took part in depressing the hyoid bone; but it was especially remarked in half the cases, that their action was notably less powerful than that of the omo-hyoid. In one experiment, in which a very weak current was employed, the omo-hyoid was alone seen to contract. We are, consequently, led to conclude that while the sterno-hyoid, sterno-

[4] Without definitely supporting this view, Gaskell (*Proc. Roy. Soc.*, vol. xliii, p. 390) shows that some large "somatic" nerve-fibres leave the facial nerve between its origin from the bulb and its exit from the stylo-mastoid foramen. He suggests that some of them may possibly form a nerve to supply the levator palati, but he leaves their real destination undetermined.

[5] I desire to add here that Dr. Felix Semon, in the course of some experiments (unpublished), performed in conjunction with myself, found that in the dog the levator palati was innervated by the eleventh nerve.—V. H.

thyroid, and omo-hyoid muscles are all set in action by excitation of the first and second cervical nerves, the first two muscles are relatively supplied by the former nerves, while the second nerve is especially connected with the omo-hyoid muscle.

Descendens Noni.—We prefer to mention here the results of exciting this nerve, inasmuch as we regard its motor fibres to be derived entirely from the first and second cervical nerves. This nerve (ordinarily regarded as a branch of the twelfth cervical), when stimulated above its junction with the branch from the second cervical nerve, produced contraction of the sterno-hyoid and sterno-thyroid muscles, and, where the current employed was weak, there was no contraction of the omo-hyoid; but this movement was superadded on increasing the strength of the current. We ought here to mention the opinion held by Volkmann (*loc. cit.*) that fibres ascend to the hypoglossal from the spinal rami communicantes by the descendens noni.

Third Cervical Nerve.—On stimulating the branch from this nerve, which forms the second cervical nerve just before the ansa thus formed is connected to the descendens noni, there was no action seen in the depressors of the hyoid bone; it, therefore, seems certain that these muscles are supplied with motor fibres solely by the branches from the first and second cervical nerves.

REPORT ON THE AIR OF COAL MINES.

T. G. NASMYTH, D.Sc.EDIN., M.B., AND C.M.

THE sanitary examination of air has lately attracted more attention than it probably ever has at any former period. The reasons are not far to seek—the close connection now known to exist between vitiated air on the one hand and disease on the other, and the facilities now offered to medical men and others to examine by easier and more improved methods the chemical and physical conditions of air bearing on health. These have undoubtedly led to eager search and much increased information on subjects of great importance to the physician and the general public alike. We have now an abundant literature bearing on the air of houses—one-roomed, two-roomed, and four-roomed—sewers, hospitals, and schools.

Since the late Dr. Angus Smith published his valuable work on *Air and Rain*, in which there are accounts of very long and important experiments on the air of mines, I have not been able to trace any published work on the air of mines. Dr. Smith's observations were made in the year 1863, and since then the methods of coal mining, including ventilation, have been completely altered, so that the air of the mine of to-day may be totally different from what he experienced. As I have been born and brought up in a mining district, the subject was one that naturally interested me, and the further fact that for ten years I have been medical attendant to several large collieries has given me facilities for studying it from what may be called chemical and pathological points of view. No reasons are given to explain why the subject should be carefully inquired into, as I presume they are self-evident.

Anyone who has read Dr. Smith's work will agree with me that the conditions which he found existing in mines were bad. Without entering into any details or discussion as yet into his observations I simply shall mention that, taking carbonic acid as a test and an example of the state of air found, from 339 specimens taken he got an average of 0.785 per cent. No miner at the present time would be asked to work in such an atmosphere, nor would he if asked. From fifteen to twenty years ago mine air was bad. Improved methods of ventilation were not then in general use, and the law on the subject was not so strictly enforced as now, when not only must there be ample provision for removal of the air, but measurements must be periodically made and entered into a book for the purpose, showing the volume and the velocity of the fresh air currents. The test of a candle or a lamp burning is a somewhat rough one, as it is made by the miner. When made in the manner referred to by Smith it is of more value, but the miner's method is a common one, and in "fiery" pits often such a fatal one that some reference to it may be interesting.

In talking with miners on the subject, they have told me that about twenty years ago sometimes the air was so bad that, if the lamp were unaided, it would not burn, but by constant attention it might be made to give out a feeble light, and it was frequently the duty of boys when too young or too small for harder work to trim the lamps, and keep them burning for their fathers or seniors. This is a rude test, but at the same time impresses one with the idea that the air must have been very bad. Judging from my own experiences and sensations, a very short time in a "waste" where lamps would not burn was decidedly unpleasant, and one longed for fresh air in a way hitherto unexperienced. The candle I shall yet refer to when the methods of examination are described.

Methods of Examination.—In a purely scientific investigation, other methods might have been selected, but the primary object of the inquiry being to ascertain the relationship between mine air and the miners' healths some variations are made. It must be further borne in mind by those who have not attempted this sphere for research, they must be prepared to meet with difficulties met with in mines which they would not experience elsewhere, such as absence of the light of day, limited space to work in, constrained position, risk, and injury to apparatus used. I am happy to say I cannot add difficulties put in my way, as, from miner to master, every facility was given me in my work. The growth of the microbes in Hesse's tubes was an object to the workmen of great interest and of exaggerated importance, as bearing on imagined diseased conditions attributed to these—in so many cases—harmless organisms.

Temperature of Mines.—To the meteorologist, an accurate record of the temperature of mines would doubtless be interesting, and I am not aware any have been made. The difficulties and want of facilities for making them are sufficient reasons, apart from the dangers valuable instruments are liable to in mines. The charts I have made are not valuable to the meteorologist, as they neither show the maximum nor the minimum temperatures, but show the temperatures of the wet and dry bulb thermometers at a fixed hour of the day, namely, 9 A.M. The readings were made by a highly intelligent and conscientious mine inspector whom I instructed and supervised in the readings. The readings made above ground were made by myself at the same hour of the day, for comparison with the underground thermometers.

Estimation of Ammonia.—I am sorry to say this was only an attempt, and which for many reasons had to be given up. The greatest difficulty was the cumbersome apparatus, aspirator and bottles with distilled water, and the long time consumed over the process. The method followed was that of Wanklyn, Chapman, and Smith.

Determination of Organic Matter.—There can be no doubt that the estimation of ammonia and albuminoid ammonia is the best test we yet have in obtaining from the amount of these products the amount of organic matter, but from reasons already given this method had to be given up, and the other methods suggested were the varieties of the permanganate process. The method used by Angus Smith was this, a known quantity of air is drawn through a solution of permanganate of known strength, and the amount of permanganate undecomposed is determined by oxalic acid. This method is open to many objections, for complication of apparatus, time needed, and uncertainty of results. The variety of the permanganate method I used is that of Professor Carnelley, and to whom I beg to express my great indebtedness for his kindness in giving me copies of his various papers, on the air of schools, sewers, etc., and in which the method is described. As this method is not generally known, I shall quote a description of the process from his pamphlet—a reprint from the *Transactions of the Royal Society*, June 10th, 1886.

Professor Carnelley's Method for determining Organic Matter.—The principle is reduction of potassium permanganate. The amount is determined colorometrically by comparison with a standard. The solution of permanganate used is of $\frac{N}{1000}$ strength, of which 1 cc. = 0.008 milligrammes of oxygen = 0.0000056 litre of oxygen at 0° and 760 mm. It is usually kept $\frac{N}{10}$ strength, and diluted as required, about 50 cc. of dilute sulphuric acid being added to each litre of weak solution. The samples of air are collected in well stoppered jars of about 3.5 litres capacity. The jars are filled by pumping out the air contained by bellows, and allowing the air to be examined to flow in. 0.50 cc. of standard permanganate are then run into the jar, which is then tightly stoppered and well shaken for at least five minutes. 25 cc. of the permanganate are then withdrawn by a pipette, and then placed in a glass cylinder holding about 250 cc. Then 25 cc. of the

standard permanganate are run into a similar cylinder; both are diluted up to about 150 cc., and allowed to stand for ten minutes, after which the tints of the cylinders are compared. Standard solution is then run into the decolorised solution from a graduated burette, until the tints of both cylinders are of the same intensity. The amount of solution added from the burette is a measure of the bleaching effected by the known volume of air on half the permanganate. This multiplied by 2 gives the amount. The results may either be expressed in terms of the number of cc. of the $\frac{N}{1000}$ bleached by one litre of air, or by the number of volumes of oxygen required to oxidise the organic matter in, say 1,000,000 volumes of air. Example:—25 cc. of solution from a 3.5 litre jar, in which 50 cc. had been used, required 3 cc. of the permanganate to bring it up to the standard, or the whole 50 cc. would have required $3\times2=6$ cc. This represents the number of cc. of standard permanganate bleached by $3500-50$ cc. $=3450$ cc. of air, consequently $\frac{6}{3.45}=1.74$ cc. is the bleaching effected by one litre of air.

But 1 cc. of $KMnO4=0.0000056$ litre of oxygen; $\therefore$ 1.74 cc. $KMnO4=0.000,0056\times1.74=0.0000097$ litre of oxygen is required to oxidise the organic matter in 1 litre of air, or 9.7 vols. of oxygen to oxidise the organic matter in 1,000,000 vols. of air.

The method is highly ingenious, and can be rapidly performed. Some difficulty is experienced at first in matching the tints, and with some samples of mine air, no amount of standard would bring the decolorised sample up to its colour. For the purposes to which Professor Carnelley applied this method, it has many things to recommend it; but for the air of mines, those objections to which the permanganate method is liable render the test unsatisfactory as a test for organic matter; but as a test for organic matter and other impurities coexisting, it is a most useful test. In mines we have those various substances existing which, as well as organic matter, decolorise the permanganate solution, such as sulphuretted hydrogen, nitrous acid, sulphurous acid, etc., from the combustion of gunpowder, dynamite, and burning of lamps. The results I obtained were very high in many cases, and this I attribute to the presence of these compounds, as well as to the organic matter. Professor Carnelley refers specially to the effect of oil lamps; and in mines where many hundreds are burning during work, it is no surprise that my results are high, even from this cause alone. In Carnelley's experiments he found, before burning of lamps, oxygen per 1,000,000 vols. to be 8.7, while, after, it had risen to 18.1.

Estimation of Carbonic Acid.—The method adopted was that of Pettenkoffer. The samples were collected in Winchester quarts; and an ordinary pair of bellows, with a tube attached to the spout long enough to reach the bottom of the bottles, was used to fill them with the air desired.

Estimation of Oxygen.—The method I have used is that of Franke, of Berlin, and the apparatus is associated with his name Franke's burette. It consists of a burette graduated into 50 cc., and with a bulb on either end. One end is closed by a stopcock, the other by a plug on which there is also a stopcock. This plug closes the bulb on one end. Between this bulb and the graduated part of the burette is a stopcock with wide bore. The burette is filled by allowing the air to be examined to stream through it. The two stopcocks are then closed. A quantity of water sufficient to fill the bulb at the end where the plug is inserted is introduced. The burette is then inserted into a tall cylinder of water, till the level of the water in the bulb and the cylinder is the same. The stopcock with wide bore is then opened, and by this means a volume of air at ordinary atmospheric pressure is obtained. The stopcock is now closed, water run out of the bulb, and an alkaline solution of pyrogallic acid is run into bulb sufficient to fill it completely. The plug, open, is then inserted, and stopcock closed; then the stopcock with wide bore is opened, and the absorbing solution is allowed to run into graduated part, where it is slightly shaken. The solution is then run back to bulb, and stopcock closed. After this the absorbing solution is run out entirely, the bulb washed out with water, finally filled with water, and plug inserted. The burette is then placed in the tall cylinder of water, and stopcock with wide bore opened; the height of water in the burette is read off at same water level as of cylinder, and this gives the volume of oxygen per cent. The volume is then calculated for temperature and pressure. I cannot vouch for the accuracy of the instrument, but it is very handy, and at least gives comparatively accurate results.

Method for Estimation of Micro-Organisms.—The method of Hesse is by far the best in present use, and this was the one used by me. Koch's own method is useful so far, but the results are not quantitative. When specimens are only desired, and not an idea of the number for a given volume of air, Koch's method is useful, likewise the method of simply exposing plates with nutrient jelly to the air to be examined, or sterilised potatoes, bread, etc.

Hesse's Apparatus.—This consists of a glass cylinder about 18 inches long and 22 inches in diameter. At one end a piece of india-rubber sheeting is stretched and firmly bound round the end of the glass cylinder to prevent air sucking past it. The other end of the glass cylinder is closed with a tight-fitting plug of india-rubber, through which a glass tube passes. From this tube passes a piece of india-rubber tubing to a litre bottle filled with water, and from this bottle to a second litre bottle another tube passes; when not in action this tube is pinched off. Along the bottom of the glass cylinder are 50 cc. of nutrient jelly solid when cooled. The cylinder rests on a tripod stand similar to those used by photographers. The nutrient jelly, india-rubber caps, tubing, cylinder, etc., are sterilised in the usual manner by steaming in a steriliser repeatedly, and the tubes with their layers of jelly are kept sufficiently long before using to see that there is nothing growing on them. When we wish to operate the india-rubber sheeting is perforated by a heated needle or pin making a very small hole, and the pinchcock is screwed slack; water passes slowly from the upper to the lower bottle, and when it is empty a litre of air has been supposed to pass into the cylinder, and to deposit its contained microbes. As many litres of water as desired can be run out simply by reversing the position of the bottles. When the air is very foul one litre will be sufficient, as the colonies otherwise would be too close and run into each other. When the operation is over sterilised india-rubber caps or pieces of cotton-wool, also sterilised, are bound over the ends of the Hesse tube, and it is then placed in either an incubation chamber or other suitable place. After a week or ten days longer the colonies may be counted. At one time the glass cylinders were used with a coating of jelly all round the interior, but this is difficult to obtain, and in practice it is found that the microbes gravitate and settle on to the layer on the bottom of the tubes. The method of Hesse is very elegant, and has many advantages; from the length of the surface of the jelly exposed separate colonies form, often giving pure cultivations, and their growth can be studied as on a glass plate, and inoculations can readily be made in the usual manner. There are undoubtedly objections, some of which apply to all bacterial methods, and others which apply specially to this one in particular, struck me, and I have not heard it referred to by any other. It is this: Although you run off a litre of water, and although the capacity of the glass cylinder is also about a litre, it does not follow that a litre of air has been drawn from the outside. The first half of the air contained in the glass cylinder may be removed, but after that, or even before it, the air from the outside and the air inside diffuse and commingle, so that a mixture of these will be aspirated out, and in consequence a litre of air will not have passed in. There can be little doubt about this, so that as a quantitative test the method is defective. Another objection is that you cannot be sure all microbes are deposited; true, we find in practice that the colonies are found in greatest abundance at the end furthest from the aspirator, and gradually diminishing inwards. Tyndall's researches bring out this point, and if we directed the beam of an electric light into one of those tubes, doubtless we would find floating particles long after we expected. Notwithstanding these objections the method is the best we have, and likely to remain so for some time.

Methods of Ventilation.—An inquiry regarding the condition of the air of mines would be incomplete without reference being made to the methods adopted to secure purity. Ventilation implies two conditions: removal of impure and the substitution of pure air, and those conditions may be obtained either by, first, natural methods, such as by the action of winds, changes produced by alterations in temperature or pressure, or by the diffusive tendencies of gases; secondly, artificial methods. We have such examples as the action of fires, fans, jets of steam, steam pipes, etc. The principles of these, however, are not different from natural methods. In the cases of those mines which came under my notice, the variety of artificial methods adopted was the fan method applied on the principle of propulsion. Whether the propulsion method or the vacuum method is the better I cannot decide, and this point falls more under the consideration of

mining engineers. In the *Transactions of the Mining Institute of Scotland* there are interesting papers on the subject, but which leave one undecided on a point which is worth clearing up. For this purpose experiments were made; but as these were not made under exactly similar conditions, they are not comparable, and the tests applied were rather to ascertain the differences in volume of air passed through the mine by the propulsion and vacuum methods, as well as the power of steam engine needed in either case, than the actual chemical condition of the air of the mine under those two different processes. I would therefore suggest that to determine which method of the two is better, not only the volume but the chemical nature of the air should be determined. Of the fans ordinarily used the Guibal, Waddle, Pelzer are most highly spoken of.

At one time fires were very commonly used, and these were either at the bottom or the top of a shaft. In the former all the heat was utilised to diminish the density of the air, and in consequence a larger volume was discharged, but there was a great danger to the mine from the fire itself; but great volumes of air can be discharged by this method, and I have read accounts of 200,000 to 400,000 cubic feet per minute being discharged by a ventilating furnace. I have not had any experience of ventilation by jets of steam or compressed air. By Act of Parliament, all mines in which twenty men or upwards are employed must have two shafts. Usually one of these is used for conveying pure air into the mine and the other for removal of the impure. The former is called the downcast and the latter the upcast. If there is only one shaft, by dividing it into two by means of a partition called a mid-wall, extending from the mouth of the shaft to the bottom, a downcast and an upcast are secured, and a fan or ventilating furnace is placed in connection with one or other. The sectional area of these shafts and the working capacity of the fan determine the volume of air there can be passed into the mine either by the plenum or vacuum methods. The distribution of the air through the mine is a question of mining detail, and the completeness of this determines very much the efficiency of the system. Formerly one main gallery or passage was used to carry the air completely round the workings, but nowadays it is split up by branches to the different workings, and this is a great improvement. If from any reason the main air current was interrupted, the whole workings beyond this point were deprived of air; but by splitting up the current this great objection is removed. It is recommended that splitting of the main air current should commence as near the bottom of the downcast shaft as possible, and should finish as near the bottom of the upcast as possible, splits of air far in the interior of the workings having comparatively little effect in increasing the quantity of air (Atkinson *On Gases met with in Mines and Ventilation*).

To carry out the process of splitting, mechanical devices, such as double doors, stoppings, bratticing, are needed, but which require no further reference from me, being details belonging to the duties of mining engineers. In practice the mechanical details involve a great amount of skill, and the success of all methods of ventilation depends upon the manner in which these complicated details are carried out. However efficient a ventilating fan may be or powerful the motive power, the combined efforts may be defeated by defective stoppings or injudicious splittings, or other defects of the various ingenious methods used, I can only speak of the various mines I have personally examined. and the experience obtained so far has been expressed by the results of the numerous chemical examinations made. The conclusions drawn from these have been already stated, and which showed the generally satisfactory state of air. What now remains is to show from actual measurements by the anemometer the quantity of air passed into those mines which were examined by me.

It will be noticed how much the quantities vary in these tables, but the stables referred to were in four different pits, some situated in the downcast and some in the upcast shaft, and different depths in each. The effect will be seen by the increase of carbonic acid when the air is in the stables or past the stables. The organic matter is also increased by the stables, and micro-organisms I have invariably found to be enormously increased when the samples were taken in the stables. A suggestion naturally follows that, when possible, stables should be placed in the upcast shaft, as the air from the stables when in the downcast shaft must undoubtedly diffuse all over the mine, and vitiate it seriously. More attention should be directed to keep the stables as clean and sweet as possible by having impervious floors, and by the use of a liberal supply of water to sweep out impurities. Moss litter has been found to have a good effect in improving the air, probably by absorbing ammonia.

In the last Mines Act a clause occurs by which it is ordered that stables must be ventilated by a current of air passing round them. This in the interests of the ponies is satisfactory, but if

Volume of Air measured by Anemometer.

—	—	Section Area of Course.
Cubic feet per minute	14.345	—
Moderately deep mine	14.784	—
,, ,,	12.730	—
,, ,,	13.065	—
,, ,,	9.900	—
,, ,,	8.000	—
,, ,,	7.590	—
Deep mine	50.400	16 × 7
,,	50.621	—
,,	51.520	—
,,	52.080	—

In the following Table the Effect of Underground Stables will be shown as regards CO_2 Oxydisable Matter and Micro-organisms.

Carbonic Acid per 1,000.	Oxygen per 1,000,000.	Microbes per Litre.	Remarks.
2.175	—	Countless	In stables.
0.489	—	—	Near bottom.
0.610	—	—	Past stables.
—	—	Sixteen points	Near stables
—	35 vols.	—	—
—	Matchless	Countless	In stables.
1.757	16	—	Front of stables.
1.778	20	—	Past stables.
2.205	27	—	Front of stables.
2.595	32	—	Past stables.
2.111	30	150 moulds, 50 bacteria	Stables.
1.454	10	Numerous moulds	,,
1.675	Matchless	30 moulds, 30 bacteria	1 horse in stable.
1.280	50	—	Outside stables.
2.586	Matchless	—	24 ponies in stables.
2.630	60	—	Ponies in stables.
2.209	45	—	Beyond stables.
2.796	30	—	Stables full.
3.025	60	—	12 ponies in stables.
2.404	—	—	Stables.
7.000	—	—	Stables in upcast.
7.8	—	—	—
1.15	—	—	Front of stables.
2.4	—	—	Past stables.

Table showing Effect of Distance.

Carbonic Acid per 1,000.	Oxygen per 1,000,000.	Microbes per Litre.	Remarks.
0.489	—	—	Near bottom.
0.610	—	—	Further in.
1.085	—	—	150 yards in.
2.55	—	—	2,000 ,,
2.59	—	—	,, ,,
1.906	—	—	,, ,,
1.339	—	—	,, ,,
2.112	34	—	1,700 ,,
2.868	25	—	1,900 ,,
0.964	11	25	100 ,,
1.641	13	30 bacteria, 10 moulds	400 ,,
1.822	50	—	—
1.637	60	—	700 yards in.
3.286	—	20	1,500 ,,
1.604	—	24	1,000 ,,
1.470	—	—	500 ,,
7.000	—	—	Temperature, 70° F.
4.209	—	—	1,500 yards in.
2.00	—	—	1,000 ,,
1.187	Matchless	—	100 ,,
1.653	33	—	,, ,,
5.182	40	None	Temperature, 70° F.
1.656	33	—	100 yards in.
3.025	60	—	Stables.
1.912	22	14 bacteria, 2 moulds	1,000 yards in.
1.266	32	—	100 ,,
—	52	—	400 ,,

the stables were better constructed and kept cleaner, the effect on the general conditions of the air would be beneficial.

These samples were taken from different mines. The shallow ones are the first on the list. The general effect will be seen in the almost uniform increase of the carbonic acid as the distance from the bottom of the downcast increases. In shallow pits the air at the bottom of the downcast is very good indeed, but in the deep pits I never found a sample as good as in a shallow one, as was to be expected. The oxydisable matter varies, but there are so many substances which act on the permanganate, that the effect must be variable. The micro-organisms do not seem to follow any fixed rule, as in one very bad sample as regards CO_2 there were none, and the next time I made an examination of the same air I got about twenty bacterial points per litre. Stagnation of air and high temperature are favourable circumstances to their growth, but the presence of horses or men is more so.

Table showing Relationship of CO_2 Oxygen per 1,000,000 Vols. and Microbes.

Carbonic Acid.	Oxygen per 1,000,000.	Microbes per Litre.
1.397	42	214 moulds 10 bacteria
2.111	30	150 ,, 50 ,,
5.812	—	63 ,,
–	20	41 ,,
1.267	—	26 ,,
0.820	—	16 ,,
0.811	—	25 ,,
2.175	—	countless
2.562	—	6 bacteria
2.303	—	5 ,,
8.790	—	0 ,,
2.630	60	—
2.209	45	—
2.796	30	—
1.187	matchless	—
2.856	39	—
1.352	15	—
1.912	22	16 bacteria
5.182	40	0 ,,
2.628	30	28 bacteria
0.964	11	25 ,,
1.454	10	countless
1.675	matchless	30 moulds 30 bacteria
2.063	34	17 ,,
1.641	13	10 moulds 30 bacteria
3.286	—	20 ,,
1.604	—	24 ,,
—	matchless	jelly liquid
6.000	—	5 moulds 4 bacteria
7.000	—	4 ,, 111 ,,
,,	—	5 ,, 20 ,,
1.912	22	2 ,, 14 ,,
2.628	30	4 ,, 24 ,,
2.4	—	25 ,,
2.517	—	—
1.358	—	—
2.872	—	—
2.832	—	4 moulds 10 bacteria
2.4	—	—
1.15	—	3 ,,
4.445	—	3 ,, 20 ,,

In the following table the carbonic acid is alone estimated, and the samples do not represent the condition of mines seeing that they were collected in "wastes," upcast shafts, and generally where no work was going on. The effect of barometric depression was noted on several occasions; samples were collected always at the same place in a mine, and compared with samples collected when the barometer was steady or standing high.

Those are exceptionally high results, and they do not represent the average condition of mines. In the case of the last estimation, which gave 80 CO_2 per 1,000 volumes of air, the sample was taken from a mine which had been purposely closed for a month or two, and as nearly hermetically as possible, so as to damp off a burning seam by using up the oxygen and developing carbonic acid. In practice this method alone is found sufficient. Before the place was opened I warned the workmen of the danger of going in. Lights went out at once when introduced. No one ventured in, but still it was possible to collect the samples I got, from the fact that a current of fresh air passed up to the door which closed up the mine. The bottles were introduced through this and emptied of their contained water—the only method applicable in this case.

The sample which shows 11.050 per 1,000, had a history attached to it, as in the place where it was collected, an hour before a man had succumbed to the poisonous gases given off from the burning seam referred to. The air here smelt of the combustion of coal, paraffin or naphtha being the worst apparent. The quantity of carbonic acid, though large, doubtless did not cause death, but as there would be carbonic oxide as well, the cause of death was not far to seek. Lamps burnt well enough, and this would probably be assisted by some marsh gas given off from the burning coal. The effect of these gases on individuals is peculiar; some men were overcome at once, others were not very susceptible.

Carbonic Acid.	Remarks.
5.812	Made in waste, no current, lamps dim
3.811	In mine after explosion of blasting powder
3.4	Upcast shaft.
3.5	,, ,,
4.066	,, ,,
4.012	,, ,,
11.050	Taken in mine where fatal case had occurred
3.025	In stables with twelve ponies in
5.182	In foul shaft, 1,500 yards in
3.377	—
6.000	Bottom of upcast shaft
7.000	,, ,, ,,
3.286	1,500 yards from bottom of shaft
7.000	Barometer rising after fall
4.579	Low barometer
4.8	,, ,,
7.581	,, ,,
7.261	Barometer rising after severe fall
6.999	,, ,, ,,
5.182	Barometer high ,, ,,
20.000	Air passing from burning seams
80.000	Air in mine closed for burning seam

Table showing Percentage of Oxygen.

Oxygen per Cent.	Remarks.
20.3	Sample taken 1,500 yards from downcast
20.2	,, 1,000 ,,
20.6	Bottom of pit
20.3	Stables in pit
20.4	50 yards from bottom
20.3	,,
20.1	Bottom of upcast shaft
19.8	Stables in upcast pit, temperature 68° F.
20.4	Sample 1,500 yards from downcast
20.6	,, 1,000 ,,
20.6	,, 500 ,,
20.0	,, 1,000 yards in, temperature 70° F.
18.0	Stythe from burning coal
20.4	1,500 yards from downcast
19.9	Outside stables in upcast pit
19.4	Inside ,,
19.1	1,000 yards in upcast, temperature 70° F.
18.9	,, ,, ,,
4.0	In this sample there was 80 per cent. of CO_2. Seams on fire and section built up

Results Compared.

Carbonic Acid per Cent.	Oxygen per 1,000,000 volumes.	Oxygen per Cent.	Situation.	Authority.
0.181	30	—	shallow mines	
0.219	39	20.40	deep mines	
—	—	20.26	,,	Smith
0.785	—	—	—	,,
0.10	—	—	barracks	Chaumont
0.216	—	—	schools	Endeman
0.245	—	—	,,	Weaver
0.112	—	—	one-room house	Carnelley
0.099	—	—	two ,,	,,
0.077	—	—	four ,,	,,
0.186	—	—	school	,,
0.123	—	—	,,	,,
0.133	—	—	factory	,,

Table showing Average of Results.

	Per Cent.
Carbonic acid in moderately deep mines	0.181
Carbonic acid in deep mines over 100 fathoms	0.219
Oxygen in deep mines	20.40
Oxygen required to oxidise 1,000,000 volumes of air:	
Moderately deep mines...	30
Deep mines	39

As I accompanied the rescue party with the hope that artificial respiration might not be too late to restore the man, I can speak from experience of the effect produced.

The action of the heart was increased, not from the excitement of the situation, I believe, as I again experienced this on a second visit, some slight oppression of breathing and giddiness, and a tightness over the forehead as long as I remained in the foul place. There was not much else to be felt, but on reaching the fresh air there was very marked giddiness, weak fluttering action of the heart, and almost syncope, followed by severe headache and thirst. The experience of others was similar, with pain in the loins and loss of power of the limbs, and, in those overcome, unconsciousness and vomiting on return to consciousness. Those symptoms look like poisoning by carbon disulphide, and no doubt this is present in the stythe from the burning coal. In regard to the relationship that exists between barometric conditions and the presence of explosive gases in mines, it is usually stated that with a low barometer there is danger of explosions, but there is as much with a variable condition of the barometer, and especially with a rise subsequent to a low barometer. The mines I have examined are not fiery, hence I could not trace any relationship such as the above, and as there is no very good method of examining carburetted hydrogen accurately, I cannot speak regarding this connection; but assuming that carbonic acid gas might be used as an indicator of other gases, I have examined the quantities of carbonic acid at a fixed place at a mine under those varying conditions referred to, and I certainly found that with a low barometer, or with a rising one, I got much larger quantities present than when the barometer was steady or high. At the place I selected for testing the point, the quantity of carbonic acid usually found was from 3 to 4 volumes per 1,000 with a low barometer, or with a rising one after a fall I got from 5 to 7 volumes per 1,000. This part of the subject demands further attention, and which I hope yet to give it.

Micro-Organisms in Coal Mines.

Hesse's process is useful, both as a convenient method for collecting and estimating the number of colonies in a given quantity of air, but also we are enabled to observe any special features in the growth of these colonies, and from them further to make pure cultivations when so desired. The conditions of growth in the air of mines are totally different from those found above ground, the absence of sunlight, the presence of excessive moisture, and the different chemical nature of this underground atmosphere.

I have already stated that I did not find a uniform connection between impurity of air and quantity of organisms found. There seem to be various modifying circumstances contributing to these results. Where the current of air was strong there were usually few colonies found, and when the air was stagnant, there colonies were abundant. The presence of men and horses has a very great influence in affecting both the numbers and kind of colonies, increasing the former and varying the kind; where there were neither horses nor men, usually there was a crop of moulds; where men and horses were near, there bacteria were got.

General Description of Microbes found.

A. Sample made at upcast shaft, very foul air. The slides were mainly torulæ, mycelial filaments, bacilli subtiles, and some cocci. Number of colonies, 26.

B. Bottom of downcast. Torulæ and mycelial forms alone. Number of colonies, 15.

C. Upcast: bacilli, torulæ, and mucors.

D². Upcast in deep mine, very foul air. 5 penicillia, 4 bacteria.

E². Stables in upcast, air very bad. Moulds 10, bacteria 110.
Slides: bacilli, torulæ, and micrococci.
Cultivations: 1. Orange yellow in jelly.
2. Pure white.
3. „ „
4. Yellowish.

F². Bottom of upcast, foul air. Bacteria 20, moulds 5.
Slides: micrococci, torulæ, and bacilli.

G². Stables in downcast pit. 25 penicillia glauca.

H². 1,000 yards from downcast. 24 colonies.
In 10 slides: bacilli, micrococci.

I². 1,500 yards from downcast. Colonies 20.

K². 1,000 yards in. 24 points.

F. Sample made in stables.
In 10 slides there were bacilli, cocci, torulæ, and mycelial forms. Colonies countless.

G. Sample taken 1,000 yards from downcast. No work going on. Fans stopped.
In 6 slides there were mostly bacilli. 6 colonies in tube.

H. Same place as G.
In 5 slides: torulæ, micrococci, and a few bacilli. Colonies 5.

I. Sample taken in waste.
CO_2, 8 volumes per 1,000. Lamps scarcely would burn.
Slides: mostly penicillium glaucum. Colonies 62.

J. 1,000 yards from downcast. Colonies 12, bacterial moulds 8.
Slide 1: Micrococci in clusters and chains, in jelly, pale straw colour forming a very deep cup into jelly.
Slide 2: Large micrococci, bright orange in colour.
Slide 3: Micrococci, jelly liquid. Other slides: torulæ chiefly.

K. Sample near stables. 16 colonies in all; 4 of these moulds.
In 9 slides: micrococci and a few bacilli.

L. Sample in stables.
Slides: torulæ, micrococci, and bacilli.

M. Same place as L. Cocci, torulæ, and bacilli.

N. Made in stone mine, blind end, so little current two men working. Temperature 59° F. 41 colonies.
In 17 slides: bacilli, torulæ, cocci, and mycelial forms.

P. Sample 200 yards from downcast. 60 moulds, 4 bacterial growths.
Slide 1: long broad bacilli arranged in clusters show spores; others, cocci and torulæ.

Q. 500 yards from downcast. 8 moulds and 4 bacteria.

R. Made in stables. Colonies countless.

S. Bottom of pit. No work going on for four days; fan not going. Moulds 214, bacteria 10.
Slide 1: mycelial growth.
Slide 2: torulæ and bacilli, bright orange growth in tube cultivation.
Slide 3: pinkish growth in jelly, long bacilli at ends.
Slide 4: micrococci, white growth in jelly.
Slide 5: large micrococci, bright yellow growth in jelly.
Slide 6: orange growth in jelly, large micrococci.

T. Made in stables. Moulds 150, bacteria 50.
Slide 1: impure mycelia and micrococci.
Slide 2: micrococci, pearly white growth in jelly.
Slide 3: micrococci or torulæ, straw-coloured growth in jelly.
Slide 4: jelly liquefying micrococci.
Slide 5: large micrococci, orange growth in jelly.
Slide 7: large bacilli like bacillus anthracis, jelly liquid.
Slide 9: Straw-coloured growth, cup-shaped and yellow in colour; micrococci.
Slide 10: micrococci, jelly liquid.

U. Made in stables. Moulds countless.

V. Sample opposite stables in pit. 150 fathoms deep near downcast. 25 colonies.
Slides: bacilli and micrococci.

W. Stables of deep pit. Moulds 3, bacteria 30
Slides: bacilli, torulæ, and mucor growths.

X. Near downcast deep pit. 17 colonies.
Slides: micrococci, torulæ, and bacilli.
Cultivations four in number.

Y. Sample 400 yards from downcast. 10 moulds, 30 bacteria.
Slides: micrococci, torulæ.
Cultivations seven in number.

A¹. Sample made in *cul-de-sac* 1,000 yards from downcast. Moulds 4, bacteria 24.
Slides: nearly all micrococci.
Cultivations: 1. Pearly white growth on surface forming a ring round a central growth (drawing).
2. Delicate pink in jelly.
3. Liquefying.

B². 1,000 yards from downcast. Temperature 60° F. 14 colonies. bacilli and micrococci.

C². 1,500 yards in. No growth at all.

D². Made in upcast. 5 penicillia, 4 bacteria. Consisting of micrococci.

E². Stables in upcast. Moulds 10, bacteria 110.
Slides 8 in number, showing bacilli, torulæ, and micrococci.
Cultivations: 1. Impure.
2. Pure white growth in jelly, small round cocci.
3. Same as No. 2.
4. Yellow growth, cocci in clusters and chains.

F². Bottom of upcast. Bacteria 20, moulds 5.
In 10 slides: micrococci, torulæ, and bacilli.
H². 1,000 yards from downcast. 24 points.
10 slides: mostly micrococci; some show bacilli.
I². 100 yards from bottom of downcast. 4 points.
Slides show micrococci and mycelial forms.
K². Sample in stables. 30 penicillia, 20 bacteria.
8 slides: mostly micrococci and bacilli.

Underground Temperature.—I have already mentioned the plan that was adopted, and that the results are not intended to be at all strict meteorological records, but simply to show as near as possible the average temperature of a mine at a fixed time of the day. The thermometers, wet and dry bulb, were put in airway, through which the air coming from the surface had travelled 1,000 yards. The observations began in September, 1887, and terminated January, 1888.

Peculiarities of Records.—The highest temperatures recorded were on September 9th, when 55° F. was indicated at the thermometer above ground; in the mine the temperature was 55.5°. The lowest temperature above was on December 22nd, 25°; in the mine on the day the temperature was 53°. The smallest difference between the temperatures above and below occurred on September 9th, when the temperature in the mine was only half a degree higher than above ground. The greatest difference was on December 22nd, when the temperature was 28° higher below than on the surface. The highest temperature in the mine was 55.5°. The lowest temperature in the mine was 53°, and this temperature was recorded on twenty-one consecutive days, showing an extraordinary uniformity of temperature. The greatest difference below was 2.5°. The greatest difference above in two consecutive days was 14°, while below it was only 1°. The relative humidity below varied from 93° to 100°; practically the air is nearly always saturated. This excessive humidity is certainly not desirable from a sanitary point of view, but I do not know any bad consequence to the health of the miners. The uniformity of temperature is certainly favourable; there are not the great vicissitudes of temperature as above ground, nor the biting blasts.

It is a fact well known that ponies and horses soon improve in condition in mines; their coats shine in a way which can only occur with much grooming above ground, and which they certainly do not get below; and in spite of hard work I have known ponies to be 20 years below ground, and at a time when the ventilation was very bad and the working hours longer than now. The chart showing the whole range of temperatures from September to January will be found at the end of this report.

In the following Tables the Temperatures of Wet and Dry Bulb Thermometers on the Surface are compared with the Readings Below at a Distance of about 1,000 yards from Bottom of Pits.

Month.	Above.			Below.			Difference. Above.		Difference. Below.	
	Dry Bulb.	Wet Bulb.	Rel. Hum.	Dry Bulb.	Wet Bulb.	Rel. Hum.	Temp	R. H.	Temp.	R. H.
	°	°		°	°		°		°	
September 8	54.0	49.0	69	55.0	51.0	93	—	—	+ 1.0	+24
,, 9	55.0	54.0	93	55.5	54.5	93	—	—	+ 5.0	—
,, 10	48.0	46.3	86	55.0	54.0	93	—	—	+ 7.0	+ 7
,, 11	49.3	48.7	93	55.0	54.7	93	—	—	+ 5.7	—
,, 12	49.0	48.0	93	55.0	54.2	93	—	—	+ 6.0	—
,, 13	45.3	43.0	85	55.0	54.0	93	—	—	+ 9.7	+ 8
,, 14	49.0	47.5	86	55.0	54.0	93	—	—	+ 6.0	+ 7
,, 15	47.0	45.5	86	54.5	54.0	93	—	—	+ 7.5	+ 7
,, 16	47.7	46.5	93	55.0	54.5	93	—	—	+ 7.3	—
,, 17	52.0	50.1	86	54.5	54.0	93	—	—	+ 2.5	+ 7
,, 18	48.3	46.5	86	—	—	—	—	—	—	—
,, 19	49.0	47.0	86	54.5	54.0	93	—	—	+ 5.5	+ 7
,, 20	48.3	47.0	93	54.0	53.3	93	—	—	+ 5.7	—
,, 21	49.4	48.5	93	54.5	54.0	93	—	—	+ 5.1	—
,, 22	50.5	49.0	86	54.0	54.0	100	—	—	+ 3.5	+14
,, 23	50.0	49.1	93	55.0	54.3	93	—	—	+ 5.0	—
,, 24	48.0	47.5	86	54.5	54.3	93	—	—	+ 6.5	+ 7
,, 25	51.7	51.0	93	—	—	—	—	—	—	—
,, 26	53.2	53.2	100	54.5	54.0	93	—	+7	+ 1.3	—
,, 27	—	—	—	54.0	53.5	93	—	—	—	—
,, 28	41.0	40.0	92	53.5	53.0	93	—	—	+12.5	+ 1
,, 29	48.5	48.3	100	54.0	53.5	93	—	+7	+ 5.5	—
,, 30	50.0	48.0	86	54.0	53.5	93	—	—	+ 4.0	+ 7
October 1	45.3	45.0	100	54.0	53.5	93	—	+7	+ 8.7	—
,, 2	—	—	—	—	—	—	—	—	—	—
,, 3	—	—	—	54.0	53.7	100	—	—	—	—

Month.	Above.			Below.			Difference. Above.		Difference. Below.	
	Dry Bulb.	Wet Bulb.	Rel. Hum.	Dry Bulb.	Wet Bulb.	Rel. Hum.	Temp	R. H.	Temp.	R. H.
	°	°		°	°		°		°	
October 4	46.0	44.5	86	54.0	53.5	93	—	—	+ 8.0	+ 7
,, 5	46.5	45.3	93	54.0	53.5	93	—	—	+ 7.5	—
,, 6	49.0	48.0	93	54.0	53.5	93	—	—	+ 5.0	—
,, 7	45.0	44.5	92	54.0	53.5	93	—	—	+ 9.0	+ 1
,, 8	40.0	39.0	92	54.0	53.0	93	—	—	+14.0	+ 1
,, 9	38.5	37.5	91	—	—	—	—	—	—	—
,, 10	—	—	—	53.5	53.0	93	—	—	—	—
,, 11	35.0	33.3	80	53.5	53.0	93	—	—	+18.5	+13
,, 12	34.0	32.0	79	53.0	53.0	93	—	—	+19.0	+14
,, 13	40.0	38.0	84	53.0	52.5	93	—	—	+13.0	+ 9
,, 14	39.0	37.0	84	53.0	52.5	93	—	—	+14.0	+ 9
,, 15	36.5	34.3	82	53.0	52.5	100	—	—	+16.5	+18
,, 16	38.0	36.0	83	—	—	—	—	—	—	—
,, 17	36.0	35.0	91	54.0	53.0	93	—	—	+18.0	+ 2
,, 18	46.7	46.0	93	54.0	53.0	93	—	—	+ 7.3	—
,, 19	46.0	44.0	86	54.0	53.5	93	—	—	+ 8.0	+ 7
,, 20	48.7	46.0	79	54.0	53.5	93	—	—	+ 5.3	+14
,, 21	36.3	35.0	91	54.0	53.0	93	—	—	+17.7	+ 2
,, 22	42.0	40.0	84	54.0	53.0	93	—	—	+12.0	+ 9
,, 23	48.0	47.5	100	54.0	54.0	100	—	—	+ 6.0	—
,, 24	34.0	31.0	72	53.0	52.5	93	—	—	+19.0	+21
,, 25	33.5	31.0	78	53.5	53.0	93	—	—	+20.0	+15
,, 26	40.0	37.0	77	53.0	53.0	100	—	—	+13.0	+23
,, 27	49.0	49.0	100	54.0	53.0	93	—	+7	+ 5.0	—
,, 28	46.0	44.0	86	54.0	53.0	93	—	—	+ 8.0	+ 7
,, 29	40.3	40.0	100	54.0	53.0	93	—	+7	+13.7	—
,, 30	38.2	37.2	91	—	—	—	—	—	—	—
,, 31	40.1	39.9	100	54.0	53.0	93	—	+7	+13.9	—
November 1	43.7	41.0	78	54.0	53.5	93	—	—	+10.3	+15
,, 2	43.0	41.5	84	54.0	53.0	93	—	—	+11.0	+ 9
,, 3	41.5	40.0	100	53.0	52.5	93	—	+7	+11.5	—
,, 4	37.3	37.0	100	53.0	52.5	93	—	+7	+15.7	—
,, 5	—	—	—	54.0	53.0	93	—	—	—	—
,, 6	43.0	43.0	100	—	—	—	—	—	—	—
,, 7	43.0	43.0	92	54.0	53.0	93	—	—	+11.0	+ 1
,, 8	44.0	44.0	100	54.0	53.0	93	—	+7	+10.0	—
,, 9	41.1	41.0	100	54.0	53.0	93	—	+7	+12.9	—
,, 10	36.0	35.0	91	54.0	53.0	93	—	—	+18.0	+ 2
,, 11	39.1	39.0	92	53.0	53.0	100	—	—	+13.9	+ 8
,, 12	37.5	36.0	91	53.0	53.0	100	—	—	+15.5	+ 9
,, 13	37.5	36.1	91	—	—	—	—	—	—	—
,, 14	34.0	33.0	89	54.0	54.0	93	—	—	+20.0	+ 4
,, 15	28.0	27.0	93	53.0	53.0	100	—	—	+25.0	+ 7
,, 16	31.0	33.8	100	53.0	53.5	100	—	—	+19.0	—
,, 17	39.5	37.0	84	53.0	53.0	100	—	—	+13.5	+16
,, 18	35.0	34.0	90	53.0	53.0	100	—	—	+18.0	+10
,, 19	36.0	35.8	100	54.0	53.0	93	—	+7	+18.0	—
,, 20	35.0	34.0	90	54.0	54.0	100	—	—	+19.0	+10
,, 21	36.2	36.0	100	54.0	53.0	100	—	—	+16.8	—
,, 22	39.0	39.0	100	53.0	53.0	100	—	—	+14.0	—
,, 23	36.5	35.0	91	54.0	53.0	93	—	—	+17.5	+ 2
,, 24	34.0	33.5	100	53.0	53.0	100	—	—	+19.0	—
,, 25	36.0	35.0	91	53.0	52.5	100	—	—	+17.0	+ 9
,, 26	48.0	47.0	93	53.0	53.0	100	—	—	+ 5.0	+ 7
,, 27	40.5	39.0	100	53.0	53.0	100	—	—	+12.5	—
,, 28	36.5	36.0	100	53.0	53.0	100	—	—	+16.5	—
,, 29	32.0	31.5	100	53.0	53.0	100	—	—	+21.0	—
,, 30	33.0	32.5	100	53.0	53.0	100	—	—	+20.0	—
December 1	47.0	46.0	93	53.0	53.0	100	—	—	+ 6.0	+ 7
,, 2	45.0	45.0	100	53.0	53.0	100	—	—	+ 8.0	—
,, 3	45.1	45.1	93	53.0	53.0	100	—	—	+ 7.9	+ 7
,, 4	35.0	35.0	100	53.0	53.0	100	—	—	+18.0	—
,, 5	35.0	35.0	100	53.0	53.0	100	—	—	+18.0	—
,, 6	41.0	40.0	92	53.0	52.5	100	—	—	+12.0	+ 8
,, 7	31.5	31.0	100	53.0	53.0	100	—	—	+21.5	—
,, 8	32.5	31.5	100	53.0	53.0	100	—	—	+21.0	—
,, 9	31.0	31.0	100	53.0	53.0	100	—	—	+19.0	—
,, 10	27.0	—	—	53.0	52.0	93	—	—	+26.0	—
,, 11	25.0	—	—	—	—	—	—	—	—	—
,, 12	29.0	—	—	53.0	52.5	100	—	—	+24.0	—
,, 13	40.0	39.0	92	53.0	53.0	100	—	—	+13.0	+ 8
,, 14	35.0	34.5	100	53.0	53.0	100	—	—	+18.0	—
,, 15	36.0	35.0	91	53.5	53.0	100	—	—	+17.5	+ 9
,, 16	41.0	41.0	100	53.0	53.0	100	—	—	+12.0	—
,, 17	37.0	35.0	83	53.0	53.0	100	—	—	+16.0	+17
,, 18	—	—	—	—	—	—	—	—	—	—
,, 19	30.0	—	—	53.0	53.0	100	—	—	+23.0	—
,, 20	34.0	33.0	—	53.0	53.0	100	—	—	+19.0	—
,, 21	30.0	30.0	—	53.0	53.0	100	—	—	+23.0	—
,, 22	25.0	25.0	—	53.0	53.0	100	—	—	+28.0	—
,, 23	28.0	—	—	53.0	53.0	100	—	—	+25.0	—
,, 24	34.0	32.0	79	53.0	53.0	100	—	—	+19.0	+21
,, 25	—	—	—	—	—	—	—	—	—	—
,, 26	34.0	33.5	100	53.0	53.0	100	—	—	+19.0	—
,, 27	31.5	31.0	100	53.0	53.0	100	—	—	+21.5	—
,, 28	36.5	35.0	91	53.0	53.0	100	—	—	+16.5	+ 9
,, 29	30.0	—	—	53.0	53.0	100	—	—	+23.0	—
,, 30	33.0	32.0	89	53.0	53.0	100	—	—	+20.0	+11
,, 31	31.0	31.0	—	53.0	53.0	100	—	—	+22.0	—
January 1	31.5	31.5	—	—	—	—	—	—	—	—
,, 2	29.0	29.0	—	—	—	—	—	—	—	—

Month.		Above.			Below.			Difference. Above.		Difference. Below.	
		Dry Bulb.	Wet Bulb.	Rel. Hum.	Dry Bulb.	Wet Bulb.	Rel. Hum.	Temp	R. H.	Temp.	R. H.
		°	°		°	°		°		°	
January	3	33.0	32.0	—	—	—	—	—	—	—	—
,,	4	46.0	45.0	—	53.5	53.0	100	—	—	+ 7.5	—
,,	5	40.0	40.0	100	54.0	53.0	93	—	+7	+14.0	—
,,	6	36.0	35.5	100	53.5	53.0	100	—	—	+17.5	—
,,	7	40.2	40.0	100	54.0	53.5	100	—	—	+13.8	—
,,	8	48.0	48.0	100	—	—	—	—	—	—	—
,,	9	47.0	46.8	100	54.0	53.5	100	—	—	+ 7.0	—
,,	10	—	—	—	54.0	53.5	100	—	—	—	—

In the following Tables, Readings of Wet and Dry Bulbs, Thermometers on Surface are compared with Readings made at the Bottom of Pit.

Month.		Above.			Below.			Difference. Above.		Difference. Below.	
		Dry Bulb.	Wet Bulb.	Rel. Hum.	Dry Bulb.	Wet Bulb.	Rel. Hum.	Temp	R. H.	Temp.	R.H.
		°	°		°	°		°		°	
January	11	44.0	43.5	100	54.0	53.5	100	—	—	+10.0	—
,,	12	33.5	33.0	89	53.5	53.0	93	—	—	+20.5	+4
,,	13	35.0	34.5	100	53.5	53.0	93	—	+7	+18.5	—
,,	14	35.0	34.5	100	54.0	53.5	100	—	—	+19.0	—
,,	15	—	—	—	—	—	—	—	—	—	—
,,	16	35.0	34.5	100	44.5	44.0	92	—	+8	+ 9.5	—
,,	17	33.0	32.5	100	41.0	40.5	100	—	—	+ 8.0	—
,,	18	33.5	33.0	89	42.0	41.0	92	—	—	+ 8.5	+3
,,	19	24.0	24.0	100	38.0	37.5	100	—	—	+14.0	—
,,	20	32.5	32.0	89	40.5	40.0	92	—	—	+ 8.0	+3
,,	21	42.0	41.0	92	44.0	43.5	100	—	—	+ 2.0	+8
,,	22	—	—	—	—	—	—	—	—	—	—
,,	23	44.5	44.0	92	47.0	46.5	100	—	—	+ 2.5	+8
,,	24	46.0	45.0	93	48.0	47.5	100	—	—	+ 2.0	+7
,,	25	47.0	46.0	93	48.0	47.5	100	—	—	+ 1.0	+7
,,	26	38.0	37.0	91	45.0	44.0	92	—	—	+ 7.0	+1
,,	27	33.0	32.0	89	42.0	41.0	92	—	—	+ 9.0	+3
,,	28	28.0	27.0	—	38.0	37.0	91	—	—	+10.0	—
,,	29	—	—	—	—	—	—	—	—	—	—
,,	30	31.0	30.0	—	38.0	37.0	91	—	—	+ 7.0	—
,,	31	32.5	31.5	89	40.5	40.0	92	—	—	+ 8.0	+3
February	1	29.0	28.0	—	39.0	38.0	92	—	—	+10.0	—
,,	2	31.0	30.0	—	38.0	37.5	100	—	—	+ 7.0	—
,,	3	38.0	37.0	91	39.0	38.5	100	—	—	+ 1.0	+ 9
,,	4	41.0	40.0	92	46.0	45.5	100	—	—	+ 5.0	+ 8
,,	5	—	—	—	—	—	—	—	—	—	—
,,	6	42.0	41.0	92	49.0	48.0	93	—	—	+ 7.0	+ 1
,,	7	38.0	37.0	91	48.0	47.5	100	—	—	+10.0	+ 9
,,	8	44.0	43.0	92	49.5	49.0	93	—	—	+ 5.5	+ 1
,,	9	38.0	37.0	91	45.0	44.5	100	—	—	+ 7.0	+ 9
,,	10	35.0	34.0	90	44.0	43.5	100	—	—	+ 9.0	+10
,,	11	31.0	30.0	—	42.0	41.5	100	—	—	+11.0	—
,,	12	—	—	—	—	—	—	—	—	—	—
,,	13	32.0	31.0	87	42.5	42.0	92	—	—	+10.5	+ 5
,,	14	30.0	29.0	—	40.5	40.0	92	—	—	+10.5	—
,,	15	30.0	29.0	—	40.5	40.0	92	—	—	+10.5	—
,,	16	28.0	27.0	—	39.0	38.5	100	—	—	+11.0	+13
,,	17	32.0	31.0	87	40.0	39.5	100	—	—	+ 8.0	+13
,,	18	34.0	32.0	79	42.5	42.0	92	—	—	+ 8.5	+13
,,	19	33.0	32.0	89	41.5	41.0	92	—	—	+ 8.5	+11
,,	20	33.0	32.0	89	42.0	41.5	100	—	—	+ 9.0	+13
,,	21	32.0	31.0	87	41.0	40.5	100	—	—	+ 9.0	+13
,,	22	32.0	31.0	87	41.0	40.5	100	—	—	+ 9.0	—
,,	23	31.0	30.0	—	40.5	40.0	92	—	—	+ 9.5	—
,,	24	32.0	31.0	87	41.0	40.5	100	—	—	+ 9.0	+13
,,	25	28.0	27.0	—	39.5	39.0	92	—	—	+11.5	—
,,	26	—	—	—	—	—	—	—	—	—	—
,,	27	37.0	36.0	91	46.0	45.5	100	—	—	+ 9.0	+ 9
,,	28	36.0	35.0	91	45.5	45.0	93	—	—	+ 9.5	+ 2
,,	29	34.0	33.0	89	44.5	44.0	92	—	—	+10.5	+ 3
March	1	35.0	34.0	90	44.5	44.0	92	—	—	+ 9.5	+ 2
,,	2	33.0	32.0	89	43.0	42.5	100	—	—	+10.0	+11
,,	3	32.0	31.0	87	41.0	40.5	100	—	—	+ 9.0	+13
,,	4	—	—	—	—	—	—	—	—	—	—
,,	5	31.0	30.0	—	39.0	38.5	100	—	—	+ 8.0	—
,,	6	37.0	36.0	91	44.5	44.0	92	—	—	+ 7.5	+ 1
,,	7	45.0	44.0	92	45.0	44.5	100	—	—	—	+ 8
,,	8	46.0	45.0	93	45.0	44.5	100	+1	—	—	+ 7
,,	9	47.0	46.0	93	48.0	47.5	100	—	—	+ 1.0	+ 7
,,	10	47.0	46.0	93	48.0	47.5	100	—	—	+ 1.0	+ 7
,,	11	—	—	—	—	—	—	—	—	—	—
,,	12	29.0	28.0	—	40.5	40.0	92	—	—	+11.5	—
,,	13	31.0	30.0	—	42.0	41.5	100	—	—	+11.0	—
,,	14	29.0	28.0	—	40.0	39.5	100	—	—	+11.0	—
,,	15	29.0	28.0	—	41.0	40.5	100	—	—	+12.0	—

Month.		Above.			Below.			Difference. Above.		Difference. Below.	
		Dry Bulb.	Wet Bulb.	Rel. Hum.	Dry Bulb.	Wet Bulb.	Rel. Hum.	Temp	R H..	Temp.	R.H.
		°	°		°	°		°		°	
March	16	27.0	26.0	—	39.0	38.5	100	—	—	+12.0	—
,,	17	26.0	25.0	—	39.0	38.5	100	—	—	+13.0	—
,,	18	—	—	—	—	—	—	—	—	—	—
,,	19	35.0	34.0	90	41.5	41.0	92	—	—	+ 6.5	+ 2
,,	20	34.0	33.0	89	41.0	40.5	100	—	—	+ 7.0	+11
,,	21	39.0	37.0	84	46.0	45.5	100	—	—	+ 7.0	+16
,,	22	40.0	39.0	92	47.0	46.0	93	—	—	+ 7.0	+ 1
,,	23	38.0	37.0	91	45.0	44.5	100	—	—	+ 7.0	+ 9
,,	24	41.0	40.0	92	46.0	45.5	100	—	—	+ 5.0	+ 8
,,	25	—	—	—	—	—	—	—	—	—	—
,,	26	40.0	39.0	92	44.5	44.0	92	—	—	+ 4.5	+ 8
,,	27	42.0	41.0	92	46.0	45.5	100	—	—	+ 4.0	—
,,	28	41.0	40.0	92	54.0	43.0	92	—	—	+ 3.0	+ 8
,,	29	43.0	42.0	92	45.0	44.5	100	—	—	+ 2.0	+ 8
,,	30	42.0	41.0	92	43.0	42.5	100	—	—	+ 1.0	+ 8
,,	31	41.0	40.0	92	42.0	41.5	100	—	—	+ 1.0	+ 8
April	1	—	—	—	—	—	—	—	—	—	—
,,	2	43.0	40.0	78	42.0	41.5	100	+1	—	—	+22
,,	3	42.0	40.0	84	42.0	41.5	100	—	—	—	+16
,,	4	43.0	41.0	84	43.0	42.0	92	—	—	—	+ 8
,,	5	45.0	43.0	85	43.0	42.5	100	+2	—	—	+15
,,	6	48.0	47.0	93	45.0	44.5	100	+3	—	—	+ 7
,,	7	46.0	44.0	86	45.0	44.5	100	+1	—	—	+14
,,	8	—	—	—	—	—	—	—	—	—	—
,,	9	41.0	39.5	92	44.0	43.5	100	—	—	+ 3.0	+ 8
,,	10	45.0	44.0	92	46.0	45.5	100	—	—	+ 1.0	+ 8
,,	11	47.0	43.0	73	47.0	46.5	100	—	—	—	+27
,,	12	48.0	43.0	67	45.0	44.5	100	+3	—	—	+33
,,	13	47.0	45.0	86	47.0	46.5	100	—	—	—	+14
,,	14	46.0	44.0	86	47.0	46.5	100	—	—	+ 1.0	+14

Opinions regarding Miners' Occupation.—In endeavouring to ascertain what are the opinions regarding the effect of the conditions of employment peculiar to miners, it is found that reference must be made to periods about twenty-five years back, so that these are not likely to apply to the conditions of the present time, owing to circumstances which have been already referred to.

In Sir John Simon's *Public Health Reports*, published by the Sanitary Institute of Great Britain, we have the benefit of his unrivalled experience of the causes that act in producing disease over long periods in England and Wales; and on page 37 in vol. ii we find the following remarks on the effect of occupation on the health of miners: "The miner, like the indoor operative, often spends his day in an ill-ventilated workplace. But the non-ventilation from which he suffers is associated in its existence and in its consequences with conditions special to the subterranean employment, and far more complex than those which belong to the non-ventilation of common workplaces. The air in which he works is air which, for his safety's sake, ought pre-eminently to be ventilated; for in most cases, not only the exhalations of human labour, but gases indigenous of the mine earth, or gases from gunpowder burnt in rock-blasting, tend incessantly to gather round him at his work as an atmosphere quite unfit for respiration." Further, the report goes on to say: "The air in ill-ventilated mines must be very greatly more impure than the air of ill-ventilated above-ground places, so considerable must be its defect of oxygen, so considerable its excess of carbonic acid, not only must it be insufficient, often almost urgently insufficient, for healthy respiration. And the same air, besides being chemically insufficient for respiration, also carries with it into the miners' lungs more or less irritant material—material which, though the air were ever so well oxygenated, would itself tend to produce bronchitis, namely, soot, grit, and the acid fumes of combustion."

Sir John goes on to discuss the conditions of health experienced in miners; bronchitis, asthma, phthisis, and cardiac disease, with the exception—and a very important exception—of the miners of Northumberland and Durham. It was found that they did not suffer from any diseases special to their employment, or in excess of other workmen. The explanation given of these striking exceptions is that these two northern counties had good ventilation in their mines. Sir John further quotes the good effect of sufficient ventilation in some Welsh mines, where the miners were reported by the manager, by the surgeon, and by some of the men themselves, to be nearly exempt from miners' asthma. Quotations might be made of opinions given by other writers, but these are generally founded on Simon's report, and the point seems to be

abundantly proved that, twenty-five years ago, at any rate, the air of mines was bad, and the effect on the health of the miners was correspondingly bad.

In the succeeding tables facts of considerable importance are brought out. In the parish of Beath we have a mean death-rate from phthisis for both sexes of 1.33 for 1,000 living. For males for the same years the mortality was 1.01, and for females 1.72. If occupation had any effect in causing an increased mortality in miners, then we would have expected a higher mortality amongst males than females. But the opposite is the case, and this in a population where adult males are almost entirely miners. The general condition of the parish is not at all favourable to a low mortality from phthisis, the soil being stiff clay, as a rule, and very wet, marshy in many places, and liable to be swept by cold winds, there being very little shelter either from trees or hills. The housing is also indifferent, and overcrowding prevails to a considerable extent. Those conditions might be expected to lead to a higher death-rate from phthisis, even without the influence of occupation. When we compare the phthisis death-rate with other places, we find, from Farr's statistics, that in years 1850-54 there was a mean mortality from phthisis of 2.811, in 1855-57 a mortality of 2.683, and in years 1857-63 a mortality of 2.574; and in Scotland, from 1858 to 1861, a mortality of 3 per 1,000, for Leith 2 per 1,000, and for Glasgow 4 per 1,000 living.

It will be at once seen that these rates exceed very much the death-rates from phthisis in an almost purely mining district. Although we have thus a low mortality from phthisis, of course it might be that the effect of occupation might show itself in increased deaths from other causes. A reference to other tables will show that for the same periods as already given, the mortality from all causes given in the mean was 15.79 per 1,000 living, and this, of course, is a tolerably low mortality. Comparing this rate with the rate for all England for twelve periods, we find that the rate of the latter exceeds this by about 4 deaths per 1,000. Coming to the last column, we have the mean age at death of miners, and the average for twelve years, we find, is 43.1. In the list of deaths I found that one miner died at the age of 86, one at 74, another at 73, and several at 69; and those men were miners when the conditions of occupation were much more unfavourable than those experienced at the present day.

Deaths in Parish of Beath from Phthisis from year 1876 to 1887, according to Sex. Total Mortality. Mean Age at Death.

Year.	Deaths per 1,000. Phthisis: Males.	Deaths per 1,000. Phthisis: Females.	Deaths per 1,000. Phthisis: Both Sexes.	Per 1,000 Deaths. All Causes.	Miners. Mean Age Deaths.
1876	1.213	0.991	1.113	16.6	43.5
1877	1.555	0.999	1.283	18.1	43
1878	0.375	0.461	0.412	17.6	37.3
1879	0.723	0.443	0.597	10.3	47.2
1880	0.349	1.691	0.956	15.1	40.5
1881	1.677	2.031	1.837	16.5	32.8
1882	1.62	1.592	1.592	15.5	53
1883	1.567	2.042	2.042	17.6	39.6
1884	0.000	1.147	1.147	15.4	51.7
1885	0.584	1.113	1.113	14.4	48
1886	1.147	1.698	1.698	14	49.7
1887	1.398	2.272	2.272	18.4	41.1
Mean for 12 years.	1.01	1.72	1.33	15.79	43.1

Average Annual Rate of Mortality to 1,000 Living from Phthisis in England for Three Periods.

Years.	Lung-Diseases.	Phthisis.	Increase.
1850-54	2.769	2.811 ...	—
1855-57	3.103	2.683 ...	0.206
1857-63	3.809	2.574 ...	0.097

Rate from Phthisis in Scotland.

Years.	Scotland.	Leith.	Glasgow.
1858-61	3	2 ...	4

General Considerations and Conclusions.—From comparison of the state of air in coal mines with that in one-room houses, schools naturally ventilated, and manufactories, it will be admitted that it is wonderfully good. The problem of mine ventilation is a difficult one, but by the use of fans it has been solved to a certain and large extent. It would not be easy, if possible, to ensure that the air of mines would be as pure as the air above ground, as so many causes are co-operating to vitiate mine air—respiration and excretions of men and horses; combustion of powder, oil, and tallow; the exudation of gases peculiar to the various minerals met with in mines; and the decomposition of wood. To keep the products of all these in moderation a large and ever-moving volume of air must pass in and out of the mine. The sectional area of the air shaft would have to be much larger than present uses demand if the impurities were to be reduced to the quantity found in pure air, but the present system might, in my mind, be much improved by attention to some points which have struck me in the present inquiry, and which I now venture to suggest to those concerned.

The miner spends about one-third of each day in the mine, and we may assume that about one-third of his excreta pass into the mine, and there remain as a source of pollution for an indefinite time. Horses are at all times in the mine, and their excreta are constantly polluting the air, and this cannot even partially be avoided. The evil produced by the former might be diminished by the use of some form of earth closet, small coal or coal dust taking the place of earth. The receptacles could be removed daily or weekly, according to circumstances. This proposal may not strike a coal owner or manager as being practicable, but it is very simple and to a certain extent it would diminish the difficulties and the cost of ventilation. As regards pollution by horses, it is not convenient always to have stables in the upcast shaft, but for the sake of the air they should be; for the sake of the horses the stables are better in the downcast, as where the stables are in the upcast pit experience proves that they do not live so long as in the downcast. Wherever the stables are, means should be taken to purify them; impermeable floors which can be washed out with water, lime-washed walls, and careful attention to daily cleaning out of litter, would all help the problem of ventilation.

Natural means should assist artificial; thus, if the mouth of the upcast shaft were bell-shaped, and by a weather-cock arrangement made so as not to face the wind, its aspirating action would assist the fan instead of rather opposing it, as it does with the present system; and in the case of the downcast a sail or brattice might be so arranged as to promote the down current. Further, in the case of the downcast, all sources of vitiation should be removed from near its mouth, such as tar, oil, paraffin, etc., and there should be no chance of currents passing from the furnace holes down the shaft.

The Work of the Miner and its Effects.—Twenty years ago air was very bad in mines; ventilation was almost unknown, and the hours were very long. Nowadays the air is generally good; ventilation is efficiently carried on, and hours of work are short. The miner works hard whilst at his work, but he has short hours and many holidays. In the tables of statistics I have shown that phthisis, contrary to general opinion, is not a common disease amongst miners; and my own everyday experience for ten years in a large mining population supports those tables. In fact, I know of no disease peculiar to miners, or any disease in excess existing among miners. I have also consulted many other medical men practising amongst colliers, and their opinion coincides with my own. In conclusion, I have to state, as my belief, that the conditions connected with miners' occupation are as favourable to health as those in the occupation of any other workmen, and this opinion is borne out by the vital statistics quoted.

REPORT ON MORPHOLOGICAL CHANGES THAT OCCUR IN THE HUMAN BLOOD DURING COAGULATION.

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Dr. Freund and Professor Haycraft,[1] working independently, have succeeded in keeping blood in a fluid state when removed from the circulation.

Dr. Freund found that if he smeared a glass vessel with vaseline, and carefully received blood into it through a greased cannula in direct communication with the artery of an animal, he could, by covering the blood so obtained with a layer of liquid paraffin, keep it from coagulating for several hours.

[1] An Account of some Experiments which show that Fibrin Ferment is absent from Circulating Blood-plasma, *Proc. Roy. Soc. Edin.*, July, 1887, and *Jour. Anat. and Phys.*, vol xxii.

Professor Haycraft found that by allowing blood to drop through a layer of liquid paraffin on to greased mica plates, he could keep the drops liquid for some time. Care had to be taken in these experiments to prevent the blood from coming into contact with a foreign body, such as a knife. This was done by everting the cut end of the vein from which the blood was to be taken over a short glass tube, the blood escaping directly into the paraffin without touching the cut edge of the vein.

Professor Haycraft also succeeded in keeping the blood fluid by pouring into a venous capsule containing some blood a large quantity of a mixture of vaseline and paraffin, and shaking this mixture from time to time with the blood. In this way blood globules were isolated by the paraffin from contact with the vascular wall. They remained fluid for some hours.

In principle all of these methods are the same. In all cases the blood is surrounded by *fluid* of a surface-tension different from its own, and which does not mix with it.

These experiments support a theory that Sir Joseph Lister advanced with so much argument and experimental evidence—namely, that blood does *not tend* to coagulate within the body; and that, when it clots in a cup or in contact with any solid matter, the clotting is brought about by the action of the solid itself on the blood.

Of course, if the blood can be removed from the body and kept in a fluid state in oil, there is no reason to agree with Sir Astley Cooper that, within the body, the vitality of the vessels prevents its coagulation.

These experiments bring one to the threshold of a most interesting inquiry as to what can be the action of a chemically inert solid—it may be a piece of metal, glass, or porcelain—when it produces, by mere contact, such important changes in the blood. The writers of this communication have set themselves to answer this question.

The methods already described for keeping blood fluid outside the body could not, for obvious reasons, be applied to the human subject, and it was our wish to obtain some method by means of which we could experiment with our own blood, and one which might be available clinically.

After some experimentation we elaborated the following method, which exceeded the anticipations we had formed of it.

This method consists in receiving a drop of blood from a carefully greased finger into a viscous fluid. The drop will sink slowly, owing to the viscosity of the fluid; and by reversing the vessel backwards and forwards it may be kept in the fluid and away from the sides of the vessel for a considerable time.

The apparatus consists in a straight cylindrical vessel one inch and a half in diameter and about a foot in length, closed at one end, and open at the other. The edge of the open end is ground perfectly level, so that a plate of glass may be adapted accurately to it.

This apparatus, having been placed with its closed end downwards, is carefully filled with castor-oil, a very viscous fluid, care being taken to prevent bubbles of air from being carried down into the tube with the oil. When the tube is completely filled with oil, blood is introduced into it in the following way:—The finger, having been rendered turgid by a bandage, is well smeared with some of the oil and plunged into the vessel; a needle is introduced, and the finger pricked beneath the surface of the oil. In this way several drops of blood may be obtained from the same puncture, and as the blood flows into the oil the size of the drops can be regulated to a nicety.

From this it will be seen that the blood so obtained comes into contact only with the tissues of the finger in the puncture, neither the surface of the skin, nor the air, nor any particle of dust being permitted to contaminate it. By gently shaking the finger, the drops may be detached from it; the finger is then withdrawn, and the drops begin to descend in the oil. The tube should next be filled to the brim with oil, and the glass plate slipped on, care being taken not to include any bubbles of air, as these tend, when the tube is inverted, to rise, and, by touching the blood, spoil the experiment.

It is well to obtain several drops of blood of various sizes in the tube at the same time; they will be seen to gradually separate the one from the other as they descend, the largest falling with the greatest rapidity. It takes an average-sized drop ten to fifteen minutes to fall one foot in such an oil. When the largest drop has nearly reached the bottom (it must on no account be allowed to touch the glass, or the experiment will fail) the tube should be inverted, and the drops will again begin to fall. It will be seen that the larger drops which have fallen in front of the smaller ones will reach them again when they arrive at the bottom of the vessel, which is now inverted. The vessel may be inverted again and again as required.

The movable glass plate is now drawn off gently; part of the oil with the drops of blood is allowed to flow into a porcelain capsule or other shallow vessel. The drops can be taken out of the porcelain vessel with a well-oiled spoon, and placed upon a glass slide. Now, as the oil and blood have no tendency to mix, the drop can, by tilting the slide, be caused to run off on to another clean glass slide, and there examined. It will be found on drawing a needle through the drop that it is perfectly fluid, there being an entire absence of any coagulation, even in the form of the minutest trace of fibrin threads.

That the blood does not coagulate can indeed be seen in another way. If the drops be watched as they fall they will be seen soon to differentiate into two parts: the corpuscles will sink to the bottom of the drop, and the clear plasma will form a layer of a faint yellowish tint at the top.

We believe that this is the first method by which human blood-plasma, unaltered physically and chemically, has ever been demonstrated except in microscopic quantity. We have kept blood fluid in castor-oil for nearly an hour, and with almost invariable success. We have had no occasion to preserve it fluid for a longer period. It is probable that, owing to the blood coming in contact with the tissues in the wound, an infinitesimal amount of ferment is set free, which will eventually cause clotting, even though the blood is surrounded by oil.

Action of Solid Matter on White Blood Corpuscles.—There are at least two sorts of white blood corpuscles in circulating blood—finely and coarsely granular—as can be seen at any time by examining the mesentery of an animal under the microscope. Now both these kinds of corpuscles when within the circulation are rounded in shape, exhibiting no amœboid movement except in those cases in which diapedesis occurs.

In the blood from our own bodies which we examined, and which was in all respects normal, both of these varieties of white corpuscles occurred.

If human blood be received on a slide at a temperature below 65° F. (=18.3° C.) the white corpuscles remain rounded. If, however, the temperature be elevated to about 68° F. (= 20° C.) they soon exhibit movement. If the temperature be raised to 74° F. (= 23.3° C.) they become almost immediately very actively amœboid.

Experiment I.—Temperature of room and oil, 70° F. (= 21.1° C.). Time, 2.51 P.M. A drop of blood was received from a well-greased finger, rendered turgid by a bandage, into a tall cylindrical vessel full of pure castor-oil (see description of method). The blood under these conditions was invariably found to have retained its fluidity after from half an hour to an hour's immersion in the oil. The finger, having been withdrawn from the tube, was wiped, and a drop of blood from the same puncture placed upon a carefully-cleaned and dust-free glass slide, where it was covered, and the cover ringed with oil to keep the blood from further contact with air and dust. This specimen was used as a test specimen. At 2.55 P.M. the blood on the slide was examined under the microscope. Amœboid movements could be distinctly seen in the white corpuscles, which became gradually more active till, at 2.58 P.M., fibrin threads were observed to be forming. At 3.3 P.M. the white corpuscles were still actively amœboid, though the field of the microscope was thickly covered with delicate fibrin threads. The blood was removed from the tube after twenty minutes' immersion in the oil, by allowing the drops, with some of the oil, to flow out of a tube into a porcelain capsule; they were then transferred with a well-greased spoon on to a glass slide, previously rendered quite clean. By tilting the slide the drop of blood was freed from the oil, and was then covered and examined. The white corpuscles were all globular, but after three or four minutes they began to become irregular in shape. The red corpuscles were crenated in almost every case, though not universally so. The white corpuscles continued to exhibit amœboid movements as long as examined (some thirty minutes), though thick fibrin threads had by this time been formed. Some of the white corpuscles, however, did not exhibit any amœboid movements, even at the end of thirty minutes, but appeared to be abnormally transparent.

This experiment appeared to us to be highly satisfactory, showing, as it did, that the blood, so long as protected by immersion in the oil, had not changed, whilst that not so protected had shown changes long before, as regards both the formation of fibrin and the amœboid movements of corpuscles. It will be observed that

when the blood has been withdrawn from the protecting medium and brought into contact with glass, an inert solid, it quickly begins to show all the phenomena of coagulation.

This experiment is sufficient in itself to prove that the condition which varied in the two cases, namely, contact with an inert solid, was the determining cause of the production, both of fibrin and the amœboid movements observed. On other occasions we repeated this experiment, corroborating, as will be seen, the truth of our previous results in all essential particulars.

Experiment II.—Temperature of the room and oil, 72° F. (=22.2° C.) The apparatus and method employed being similar to that described above, blood was examined after having remained thirty minutes in the oil. The red cells quickly became crenated, and the elementary granules ran together into masses. The white blood corpuscles, at first spherical, quickly became amœboid and transparent, remaining so long after coagulation had occurred. These results have been obtained after much experimenting and several failures, as the temperature was often varied, and led us to the conclusion that at a temperature below 65° F. (=18.3° C.) the blood was so cooled as to prevent the white cells from exhibiting their amœboid movements under any condition, although the blood would clot at that temperature, the solid matter still causing metabolic changes, though not visible motion in the corpuscles. We found also that at a temperature above 74° F. (=23.3° C.) the corpuscles became so quickly amœboid as to prevent definite observations from being made.

We believe that these experiments demonstrate conclusively that glass and other chemically inert solids act as stimuli to the white corpuscles, as indicated by the fact that they exhibit amœboid movement if the temperature permits. The stimulus is of the nature of a purely mechanical stimulus.

As a result of its action metabolic changes occur in the cells associated at certain temperatures with changes of form.

The result is in accordance with what we know of the nature of protoplasm generally, namely that it is irritable in an eminent degree, whether the stimulus be chemical, mechanical, thermal, or otherwise.

The white corpuscle, devoid of an envelope, is exposed to the full stimulating effect of mechanical irritation. When the corpuscle is examined at a temperature below 65° F., the cell no doubt is stimulated, though probably to a slighter exent, owing to the cold, and we observe no movement. This is in accordance with generally observed facts concerning the action of heat and cold on animal tissues.

A fact also worthy of notice, and previously observed, is that the white corpuscles tend to stick to glass or other solid matter. The observations of Sir Joseph Lister on the adhesive character of leucocytes in inflammatory conditions may probably be explained on the assumption that the altered tissue acts like solid matter.

Do White Blood Corpuscles Break Down during Coagulation?—The generally accepted theory, as propounded by Schmidt[2] and others, is that coagulation is the direct result of death of the blood, especially that of the white corpuscles, which in dying produce a ferment which, acting on certain constituents of the blood-plasma, produces fibrin.

Schmidt maintains that there are two kinds of corpuscles, one kind breaking down during coagulation, the other persisting.

"As soon as the blood is shed from an artery, enormous numbers of colourless corpuscles are dissolved (Mantegazza); according to Alex. Schmidt, 71.7 per cent. in the blood of the horse. The products of their dissolution are dissolved in the plasma."

We are certain of the following facts, namely, that some at least of both the fine and coarse varieties of white blood corpuscles are always found alive after coagulation, which occurs in our own blood never later than five to ten minutes after the blood has been shed. We have some drawings of moving cells in blood which had clotted two days previously.

In addition to this, however, we believe that very few, if any, corpuscles break down during coagulation, as is generally held to be the case.

If we examine a drop of blood, and note the position of several white blood corpuscles in a field, and then examine this same field after a lapse of some time, we may see some of the corpuscles showing changes other than mere amœboid motion. They are apparently breaking down. These cells, however, stain readily with dyes, and have their nuclei distinctly visible; and moreover, these peculiar changes do not occur in less than a quarter of an hour, in fact after coagulation has occurred.

In proof that cells rapidly break down when blood is shed, it is urged that the number of white corpuscles in defibrinated blood is less than in circulating blood. But conclusions drawn from such a comparison are obviously fallacious. It will be seen at once that the very fact of whipping the blood produces a clot on the whip which entangles a large number of white corpuscles, which will thus be abstracted from the blood. We have experienced ourselves, too, the difficulty there is in comparing the number of corpuscles in one specimen with those in another, especially when we have been labouring under any preconceived idea, and place more reliance on the more direct method we have employed.

We used in all cases the following method, which enabled us to examine blood in microscopic quantities; its coagulation being postponed for at any rate a few minutes, any immediate breaking down of corpuscles could not have escaped our observation.

A slide is well cleaned, so as to remove all foreign matter, and a small piece of pure, dust-free vaseline is placed upon it, and protected from dust. A cover-glass is next cleaned in the same careful manner, and brought down upon the vaseline and pressure applied, to obtain a flat, airless layer of vaseline between the two. The thumb is then rendered turgid by winding a handkerchief round its base. The thumb is next smeared with vaseline, and a drop of blood obtained by pricking it with a greased needle through the protecting layer of vaseline. The cover is then removed from the slide by sliding it to the edge and pulling it off: in this way a smooth layer of vaseline is left both on the slide and on the cover. The blood, as soon as obtained, is transferred to the slide so prepared and is covered.

Great care had necessarily to be taken to prevent particles of dust from falling on the vaseline during the few moments the cover is removed, and this was effected by holding the vaseline-covered surface downwards.

Many observations were made with this method, and drawings of corpuscles taken. In all some fifty specimens were examined, and the corpuscles in each of them drawn and counted every four or five minutes, sometimes for thirty or forty minutes, giving us a series of drawings in which the following might be observed. The corpuscles of the coarsely granular description could be seen to become at first flattened and irregular in outline, due to amœboid movement. They then lost their granules, or these retired to one part of the cell, the remainder of the cell becoming clear. This generally occurred within the first five minutes. Then strings of fibrin could be seen gradually forming. After a time the cells become very much spread out and less visible, but as long as observed they had not disappeared. This was after coagulation had occurred.

The finely granular corpuscles were observed to present the same appearance, with the exception that their fine granules did not congregate to the same extent.

In no case, therefore, were white blood corpuscles seen to break down within fifteen minutes, thus proving that the idea that some corpuscles break down at once on the shedding of the blood is not tenable.

It will also be observed that, in our experiments with castor-oil detailed above, no white corpuscles were ever observed to break down, though in all cases some became abnormally transparent after contact with the slide; this occurred, however, long after coagulation.

From these experiments we draw the following general conclusions as regards blood shed from the body. If the weather be warm, amœboid movement of white corpuscles begins after from one to ten minutes, depending on the temperature. The movement in some cases lasts for hours. In other cases the cells change in from a quarter of an hour to two or three hours, becoming pale, indistinct granular masses, with their nuclei still visible and still capable of being stained. If the weather be cold, no amœboid movement is discernible, but the other changes go on as above. Whether or not any of the cells break down after coagulation we do not discuss. When removed from the body of course they die ultimately.

Conclusion.—Solid matter mechanically stimulates the white corpuscles of the blood, leading to amœboid movements if the blood be not cooled. In any case some metabolic change, associated with formation of fibrin, occurs in the white corpuscles, whereby they are led to contribute to the production of fibrin.

[2] A. Schmidt, "Ueber den Faserstoff und die Ursachen seiner Gerinnung." *Müller's Archiv.*, 1861, pp. 545-587 and 675-721.

The stimulus in the case of exceptional cells may be so strong or so continued as eventually to lead to an apparent or real breaking down, which occurs, however, only after, and sometimes long after, coagulation is complete.

Inert Solids, and their Action on Blood-Plates.—This subject was suggested by Professor Greenfield, and the work was done by his kind permission in his wards at the Royal Infirmary. We had also the advantage of the assistance of his demonstrator, Dr. Gibson, who has large experience in working with blood-plates.

In all these experiments, the blood of patients suffering from chronic diseases was examined, as in these cases blood-plates are more numerous than in healthy individuals. The method used was in all cases the one mentioned at the commencement of this communication.

Experiment I.—Jannette MacK., aged 18, suffering from chronic phthisis. Blood was received directly from the patient's finger into castor-oil, and kept in it for half an hour. When removed from the oil it was received on to a slide, perfectly cleaned, and having upon it a drop of osmic acid. Now, it is well known that osmic acid has the remarkable property of fixing the blood immediately on coming in contact with it. Therefore, the blood from the oil, when received into the osmic acid, would be fixed in the state in which it happened to be at the time. The blood so treated was covered with a thin cover-glass, and examined with a $\frac{1}{12}$th inch water-immersion lens. When a drop of blood is mounted on a slide and examined, the blood-plates, which are round and oval in shape and float about singly in circulating blood, run together and form granular masses. The plates become sticky, adhering not only to one another, but to any solid particles in the field. They seem to change their shape, exhibiting irregular outlines. If these changes had occurred during their sojourn in the oil, we should have found granular masses and no isolated blood-plates. The blood was, however, found to be normal in character like circulating blood; the blood-plates could be seen in the fluid with their normal histological characters. They were floating about, and presented smooth outlines.

Experiment II.—Duncan McN., aged 19. Case of chronic phthisis. The blood of this patient was treated in the above manner, being in the oil about thirty minutes. When examined in osmic acid, it presented all the appearances of normal circulating blood.

Experiment III.—John M., aged about 30. Case of chronic phthisis. In this case, also, the blood was treated as before, and Dr. Gibson declared that, had he not seen the experiment, he would have believed it to be blood received from the wound directly into osmic acid.

These experiments show, therefore, that blood-plates are in no way altered by removal from the body—the formation of granular masses, their changed shapes and outline, being due to the action of solid matter.

Conclusion.—The action of an inert solid on blood-plates is much the same as its action on white blood corpuscles. It causes them to become sticky, run together, lose contour, and change their shape.

The life-history of these blood-plates has certainly not been made out. They have been described as special and peculiar elements of the blood, but their origin and ultimate destiny has never been explained. They seem, both from their appearance and by their undergoing changes on irritation, to be pieces of undifferentiated protoplasm.

These changes which we have described are the morphological changes which occur in the blood during coagulation. These experiments do not in any way determine the part played by the white corpuscles, or so-called blood-plates, in the chemistry of coagulation, although they suggest that, as far as these bodies are concerned, coagulation is the result of living metabolism rather than of death and disintegration.

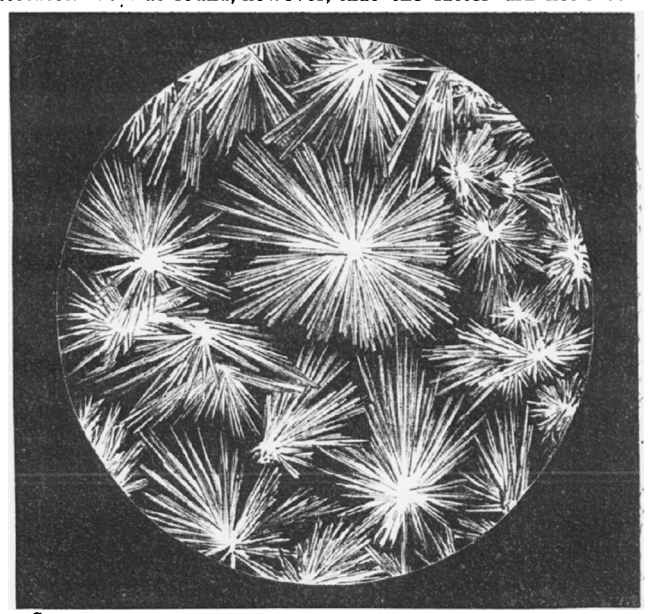
REGISTRATION OF PLUMBERS.—At the City and Guilds Institute, Finsbury, on July 30th, an examination was held, under the auspices of the Worshipful Company of Plumbers, for certificates of registration. The practical examination included various branches of lead work, and the theoretical questions relating to the several subjects of plumbers' materials, house fittings, and sanitation. Plumbers attended from Fordingbridge, Exeter, Tunbridge Wells, Ryde, Bicester, Margate, and various districts of London. The examiners were Mr. Charles Hudson, assistant-chairman of the Registration Committee, and Messrs. Ashdown, Davis, Lobb, Lyne, Millis, Smeaton, Taylor, and Webb. Rather more than 50 per cent. of those attending passed the full examination.

REPORT ON A NEW ACID FOUND IN HUMAN URINE WHICH DARKENS WITH ALKALIES (ALCAPTONURIA).

By ROBERT KIRK, M.D.Ed., F.F.P.S.Glas.

THE further investigation of this subject has led to very interesting results. Previous researches on alcaptonuria have been those of Bödeker,[1] who isolated a substance to which he gave the name of "alcapton;" of Ebstein and Müller,[2] and of Professor Smith, of Dublin,[3] the former of whom found, as they supposed, pyrocatechin in the urine and the latter protocatechnic acid. In a former paper[4] I showed that by concentrating the urine to an eighth, either slowly over the water-bath or by boiling, subsequently acidulating with hydrochloric acid, and extracting with ether a new acid was obtained, to which I gave the name of urrhodinic, which differed widely from any of the substances above-mentioned, and the properties of which explained all the peculiar reactions of the urine. This method, indeed, is actually given by Méhu[5] as a means of obtaining pyrocatechin from the urine, but none of the few who have examined cases of alcaptonuria seem to have followed it.

In further prosecuting this inquiry I have often had, as before, the co-operation of the Rev. Mr. Gibson, who has devoted much time to chemical pursuits, and the conclusion formerly arrived at as to the occurrence of a new acid in this kind of urine has been fully confirmed. Some facts previously mentioned, however, and others afterwards observed, soon made it appear that what we have called urrhodinic acid was not a simple substance but a mixture of two or more constituents, which seemed to have some relationship to each other. We were enabled to separate these by the action of neutral lead acetate. As previously stated, urrhodinic acid gives precipitates with both basic and neutral lead acetates. It was found, however, that the latter did not throw



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Uroleucic acid, crystallised from ether.

down the whole of the ingredients but left a pale yellow filtrate, which possessed the aromatic odour of the original substance, and which darkened with alkalies and exercised reducing actions as before. Further, the precipitate, if allowed to form gradually, was found to consist of two portions, a dark and a light, and both of

1 *Annal. der Chem. und Pharm.*, Band cxvii, 98 (1861).
2 *Virchow's Archiv.*, Band lxii, s. 554 (1875).
3 *Dublin Medical Journal*, vol. lxxiii, p. 465 (1882).
4 JOURNAL, November 12th, 1886.
5 *L'Urine Norm. et Patholog.*, p. 117, where, speaking of salicylic acid, he refers to the use of a mineral acid (sulphuric) as applicable to the extraction of carbolic, benzoic, and oxyphenic acid (pyrocatechin) from the urine, although under the head of pyrocatechin itself he does not again mention this.

these yielded bodies with reducing properties. We shall limit the present paper mainly to an account of the body obtained from the pale precipitate, as this has been perfectly isolated and analysed, and is probably the central component of the entire group from which the others are derived. After various trials it was found best to prepare it as follows:—

A concentrated solution of the mixed substances is prepared by dissolving them in a small quantity of hot but not boiling water, and this is filtered to remove any trace of insoluble matter. To the filtrate, which has a deep red colour, a saturated solution of lead acetate is now gradually added, and the dark precipitate which falls removed by repeated filtration. When the filtrate has become yellow, with perhaps a tinge of brown, it is transferred to a mortar, and, to avoid further dilution, some solid lead acetate is powdered amongst the solution with the pestle. In a few minutes a cream-coloured precipitate falls, consisting of the lead salt of the object of our search, with some excess of lead acetate. This precipitate is washed on a filter with water until the washings cease to have an acid reaction, is then suspended in water and decomposed by H_2S, and the resulting solution either evaporated *in vacuo* over sulphuric acid or extracted with a large quantity of ether. In either of these ways we obtain a definite compound with a marked acid reaction, which crystallises in stellate groups often coalescing to a complete scale on the surface of the glass or other vessel. It has generally been obtained of a somewhat yellow or greyish colour, but the finest specimens have been of an opaque, almost milk-white, hue; and from this circumstance we would propose to call this body "*uroleucic acid.*"

The crystals of uroleucic acid, purified by recrystallisation from ether, show a fixed melting point, which, as the result of several trials, we found to be about 133.3° C. They are resolved into a dark liquid, which boils at a somewhat higher temperature; but no odour is given off, nor does any decomposition appear to take place, although this be raised to 205° C.

Ultimate organic analysis of various specimens of this substance, prepared both by extracting with ether and by evaporation *in vacuo*, has yielded the following average percentage composition in carbon, hydrogen, and oxygen:—

C = 54.475 per cent.
H = 4.985 „
O = 40.55 „

The lowest formula corresponding to this is $C_9H_{10}O_5$; and other evidence appeared to show that this is really the rational formula of the acid, and that it is monobasic. Thus the atomic weight of $C_9H_{10}O_5$ is 198; and when caustic soda (atomic weight 40) was added to a solution of the acid in the proportion of 40 parts to 198, the latter lost its acid reaction, but not before; while beyond this proportion of soda the liquid became alkaline, and darkened if exposed to the air.

The acid is very soluble in alcohol and ether, but somewhat less in water. It gives all the reducing actions mentioned by Bödeker, but the most interesting point in this connection is the fact that it reduces bismuth, throwing down the black suboxide in abundance when boiled with Löwe's bismuth test solution. To do so, however, the solution employed must be of the strength of one-half per cent. or upwards, and hence the reason why this fact was not previously ascertained, the acid having never been isolated, and the urine not containing a sufficient quantity of it to manifest this reaction.

It gives with a one in forty solution of ferric chloride a transient green colour, instantly disappearing on diffusion of the two liquids and incapable of being rendered permanent with any proportions of the reagents. A drop of the ferric solution added to the crystals of the acid produces a red colour.

The remaining constituents of what we have called "urrhodinic" must be briefly noticed. The aromatic filtrate above referred to, left after the removal of the pale precipitate, yields an amorphous yellow substance, also with an acid reaction, and which we would meanwhile distinguish as "uroxanthic acid." It exercises the same general reducing actions, but these are not so keen, and it fails to reduce bismuth in any strength. It corresponds in all its properties to Bödeker's alcapton, which appears to have been this body in an impure state.

The dark precipitate yields a third body with an acid reaction which has been obtained as a powder, or in the form of irregular branching crystals, or as a dark oily-looking liquid. Even in strong solution this substance also fails to reduce bismuth, but it has all the other reducing powers of uroleucic acid, although these are not so intense. Our latest observations appear to show that this latter body is produced during the course of the analysis and does not exist as such in the urine. None of the above acids have been found to have any action on polarised light.

It is remarkable that this kind of urine should contain two substances possessed of reducing properties, and it is clear how this circumstance has increased the difficulty of isolating and indentifying them. It would appear that Bödeker's alcapton was, at all events, one of the bodies actually occurring in the urine, but that the secretion does not contain a trace of pyrocatechin or protocatechuic acid.

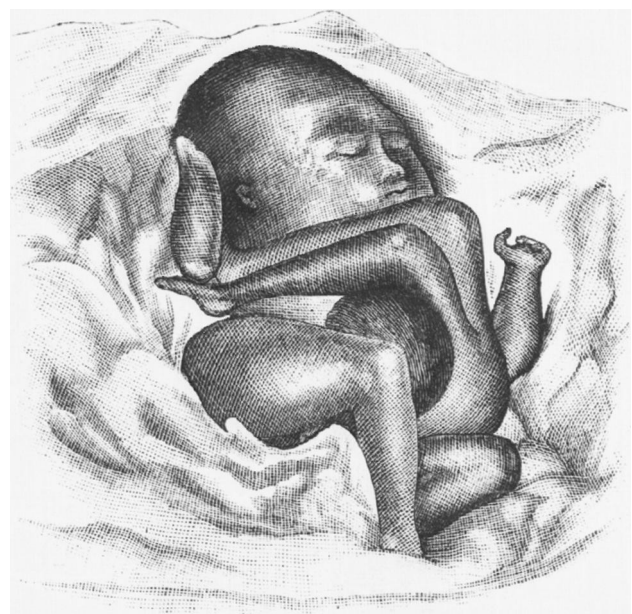
[A more detailed account of this subject will appear in the *Journal of Anatomy and Physiology.*]

A CASE OF PARASITIC FŒTUS.

By B. LANGLEY MILLS, F.R.C.S.Ed.,
Surgeon Medical Staff.

HAVING met with a very similar case of parasitic fœtus to that of Laloo, related in the JOURNAL for February 25th, 1888, I think that a few notes on it are worth recording.

Soorunophur, aged 25, primipara, was delivered of a male child on April 7th, 1888. Family history good. No history of fright during gestation. Parturition natural. The child was found to be a double monster, the growth of one-half having been arrested *in utero.* The autosite was perfectly formed, with the exception of an extra lobe to the right ear. The parasite was attached to the lower part of the sternum of the autosite, as in Laloo's case (*thoracopagus parasiticus*). The parasite was adherent to the mesial line above the ensiform cartilage. The etching, enlarged from a photograph, gives a fair idea of the condition four days after birth. Close above the adherent part of the parasite was



situated a fleshy nodule, about the size of a walnut, from which sprung two fleshy cords about two inches long, symmetrical on both sides, and free at their extremities, containing no bones, and apparently representing the upper extremities. The lower extremities were perfectly formed, and attached by a loose fold of skin over the ensiform cartilage. They were freely movable, and apparently not joined in any way to the rudimentary upper extremities. Genital organs were present in the parasite, but in a rudimentary condition. There was a urethra, but no urine passed from it. At the seat of the navel in the autosite there was a large pulsating purple tumour, about the size and colour of the bowl of a full claret glass, obscuring the remains of the umbilical cord, and being, I think, some abnormal remnants of the pedicle of the allantois.

The child died when a week old. No *post-mortem* examination could be obtained.

TWO CASES OF INJURY BY LIGHTNING: RECOVERY.

By A. H. COOK, M.B.Lond., and WILLIAM BOULTING, L.R.C.P.Lond., Hampstead.

About 1 P.M. on June 14th, 1888, W. F., aged 62, and D. H., aged 42, sawyers, were working in a wood at the Spaniards Farm, near Hampstead. There was no rain nor any sign of a thunderstorm at the time. The men were eating their dinner under an oak tree, their saws, six and a half feet long, leaning against the fence, about two feet from the trunk. One of them, F., was standing leaning against the trunk, while the other, H., was seated on a block of wood about three feet from it, with his open knife resting upon his knee. Suddenly H. "saw the clouds open and a sheet of fire falling." He heard a deafening thunder-clap, and felt stunned for some minutes, but had no sensation of pain. Then he discovered that his trousers were on fire, smoking but not blazing, and that his knife had been knocked out of his hand, and his steel buckles torn from his legs. He saw F. lying senseless on the ground and quite still, as though he were dead. He had lost all feeling in his legs, and he tumbled down when he tried to walk. His boots were "in ribbons," and fell off when he moved. He managed first to quench the fire in his trousers, and then to crawl to the road near by shouting for assistance. He was somewhat deaf, but could hear himself shout, and "felt as

Fig. 1 shows the zig-zag scar on the front of the arm, also scars on back of forearm and in groin, and mottlings over chest and flank.

though he had been blown from a cannon." F. says that he remembers nothing of the accident, and neither felt nor saw anything. Insensibility must have been instantaneous. H. managed to attract the attention of some men passing in a cart, and both men were conveyed to the infirmary, F. still quite unconscious and his clothes torn off him to such an extent that for decency's sake he had to be covered with one or two sacks on admission.

In the absence of Mr. Cook, the medical officer, they were seen by Mr. William Boulting, a neighbouring practitioner, who saw the men an hour and a half after the accident, and found them in a state of intense collapse. The features were ghastly blue, with a dull yellowish-white showing through the leaden colour. F. was almost pulseless, but became slightly conscious on being roused. H. was groaning, and complained of a burning pain as from a red hot iron, which was "travelling up his legs." Their clothes were cut from them, and F. was found to have burns on the right side from his shoulder to his feet, bearing the appearance of abrasions. The whole of this side (presumably the side on which he was leaning against the tree) had exactly the appearance of an exaggerated example of *post-mortem* staining. H. had his legs burnt in places from the point where he had been resting his knife downwards. The legs were cut probably by the steel buckles he had worn. His pulse was intermittent at the time, and for several days after the accident. Both men were so scorched that no lines were visible to indicate the course taken by the electric current, although these subsequently came out as shown in the drawings here given.

An ounce of brandy was administered to each man, the wounds were quickly dressed with boracic ointment, cotton-wool was applied, the men were covered with plenty of blankets, hot-water bottles were put to the feet, and one-quarter-grain opium suppositories were introduced. Brand's essence was given in small quantities. An hour afterwards F. vomited, and began to rally from his collapse. The wounds suppurated freely for the first two or three days. The scorching of the surface was well in a week. The burns on the right leg of H., the least injured of the two men, were well on June 25th, the eleventh day after the accident; the other leg was healed, and he was up on the twenty-first day.

F. was well three days later, and was up on July 7th. He had

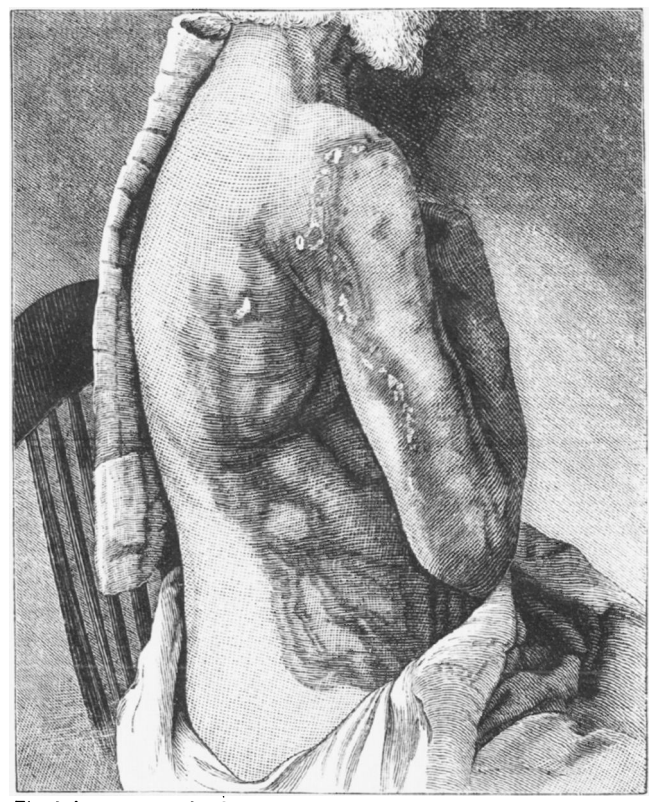


Fig. 2 shows scar on shoulder and back of arm, also a more superficial scar or mottling, like the branches of a tree, over the right side.

burns on the shoulder and the outside of the arm down to the elbow, and on the inner surface of the arm for the same distance; the forearm was scorched, the whole of the right side was scorched, and there was a burn about one inch wide running down the whole side. The scorching presented a mottled appearance over the lower part of the chest, like the branches of a tree; the groin was also burnt; the thigh had a burn three inches long, and was scorched down to the knee; the leg was scorched in front, and there was a contused wound or deeper burn over the ankle. Since the accident he had been so deaf that he could not hear a watch laid against the ear on either side or when held between the teeth.

On July 8th he complained of a ringing noise in the ears, and there was a free discharge of pus from both. On July 9th he could hear a watch at a distance of four inches from the left ear, and was much less deaf. The otoscope revealed perforation on both sides. It is possible that the otitis media may have been set up by rupture of the drum by the shock of the thunder-clap, or by prolonged exposure while in a state of collapse.

The oak tree was found to have been struck about fourteen feet above the ground, leaving a track all the way down. The exact position of the men and of the long metal saws which doubtless attracted the discharge to the tree under which they were was as follows: the fence passed close to the tree; the saws were leaning against it at a distance of about two feet from the trunk. F. was leaning with his back against the trunk about a yard, and H. on the opposite side of the fence was sitting about two yards distant from the saws. The photographs of F. show the appearance of the scars a month after the accident, the zig-zag scar down the front of the arm and the mottled appearance like the branching of a tree over the right side being well shown.

REMARKS.—The case illustrates the danger of the proximity of steel instruments during times of electric disturbance. Nor should it be forgotten that without lightning dangerous return discharges from the earth to the atmosphere may take place at a considerable distance from an atmospheric storm.

CLINICAL MEMORANDA.

CASE OF ENTIRE ABSENCE OF BOTH MAMMÆ IN A FEMALE, AGED 21 YEARS.

THE above rather remarkable case is now under the care of my assistant, Dr. Lyall, and myself. The girl is unmarried, but has given birth to a healthy male child three months ago. Dr. Lyall attended her in confinement, which was quite natural in every respect, and she has made an excellent recovery. As you will see by the photograph which I enclose there are no mammary glands,

and no trace of anything at all resembling them. She has, consequently, been unable to nurse her child. A small mole exists near where the right nipple should be found, and the pectoral muscle seems quite bare of adipose tissue in that neighbourhood. Of course there has been no trace of milk, and she has suffered from no sympathetic pain or uneasiness of any kind in that region.

Her mother tells me that she was aware of the fact that she had no breasts, but that she had always enjoyed good health and menstruated regularly from the age of 15 years.

I am not aware of mention of absence of these glands having been made by any medical men who are authorities in obstetric medicine. I have never met with such a case, and should hardly have believed such an abnormal state of things could have existed had I not seen it. Perhaps you could draw my attention to the fact that such cases have been before reported in the medical journals.

Dyneley House, Skipton. W. WYLIE, M.D.

REPORTS

OF

HOSPITAL AND SURGICAL PRACTICE IN THE HOSPITALS AND ASYLUMS OF GREAT BRITAIN, IRELAND, AND THE COLONIES.

KING'S COLLEGE HOSPITAL.

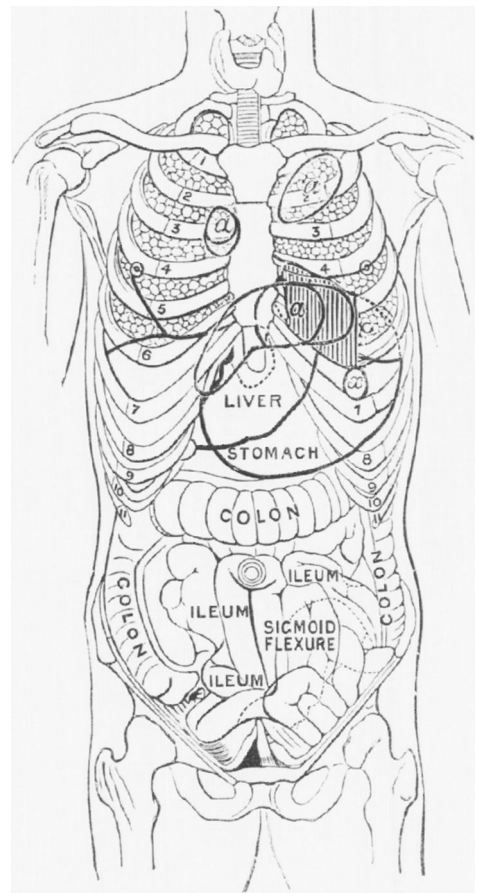
A CASE OF CARDIAC HYPERTROPHY WITH VARIABLE MURMURS: PROBABLE OCCLUSION OF THE THORACIC AORTA.

(Under the care of Dr. DUFFIN.)

[Notes and comments by Sir HUGH BEEVOR, M.B.Lond., Registrar.]

W. B., aged 24, was admitted into the hospital complaining of pain in the right side, with a temperature of 100°; these symptoms left him after a few days.

He was a soldier. He had previously had very good health; but, after two years' service, was discharged invalided. Through the kindness of the medical department at the Horse Guards, his health-sheet was obtained, where he is described, on enlistment, as a labourer with good physical development; he was sent to India, where he was in hospital on four occasions for diarrhœa and dysentery, spending 120 days out of fifteen months in hospital; he was then sent home to Netley, and, after fourteen weeks, discharged for heart disease. Habits intemperate. His brothers



and sisters are alive and healthy; the father and mother died of tumour. The chest showed a fulness below the right axilla, and strong pulsation could be felt there, and be traced up into the axilla; on the back large arteries could be traced on either side,