XIV. *On the influence of Colour on Heat and Odours. By* JAMES STARK, *M.D., of Edinburgh. Communicated by Sir* DAVID BREWSTER, *K.H. F.R.S.*

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THE influence which Colour exerts upon natural bodies has hitherto been little attended to by scientific inquirers; and notwithstanding the advanced state of science in kindred departments of research, the subject of Colour, in its more interesting relations, is nearly unknown. Though BOYLE, FRANKLIN, Count RUMFORD, Sir HUMPHRY DAVY, and Sir JOHN LESLIE, have incidentally noticed some of the effects of Colour in their investigations into the nature of heat, it does not appear that it had occurred to any of those eminent men to trace its general relations; and even in regard to heat, the inquiries of Count RUMFORD and Sir JOHN LESLIE, the latest investigators, seem to have unaccountably stopped short while a wide field of unknown properties lay in view.

PART I.

ON THE INFLUENCE OF COLOUR ON HEAT.

THE singular property of a black surface to absorb light and heat has been noticed in various forms, from the time of DESCARTES downwards. BOYLE made some experiments on light, in which colour was an element*; Sir ISAAC NEWTON demonstrated the different refrangibility of the differently coloured rays of the spectrum; and Sir WILLIAM HERSCHEL observed the different heating powers of the sun's rays on the coloured eye-glasses of his telescope†. Dr. WATSON applied the knowledge of the absorbent quality of a coating of black to the bulb of the thermometer in 1772‡, and suggested that the pri-

* BOYLE's Works, by BIRCH, vol. i. p. 725. London, 1772.

† Philosophical Transactions, 1800.

‡ Philosophical Transactions abridged, vol. xiii. p. 371.

mary colours might have different powers of receiving and retaining heat and light; but he made no experiments to verify his conjecture. Count RUMFORD, in 1792, published a series of interesting experiments, instituted with the view of ascertaining the cause of the conducting and non-conducting powers of bodies in regard to heat*; and another series of experiments by the same philosopher, chiefly made with hollow cylinders covered with various substances, was laid before the Royal Society in 1804. The result of these experiments was, "that those substances which part with heat with the greatest facility or celerity, are those which acquire it most readily or with the greatest celerity†." The effect of colour, as a modifying principle, except as to the black coating, was neither suspected nor put to the test of experiment.

Sir JOHN LESLIE followed out the idea of the absorption of heat by a blackened ball, and fabricated some ingenious instruments on this principle. Sir JOHN, however, though struck with the results of his experiments, rather inconsistently concludes, that "on the whole it appears exceedingly doubtful if any influence of that sort can be justly ascribed to colour. But," says he, "the question is incapable of being positively determined; since no substance can be made to assume different colours without at the same time changing its internal structure‡."

The only experiments of which I am aware, in which colour was proved to have a modifying effect upon the absorption of heat, were made by Dr. FRANKLIN with coloured pieces of cloth laid out in sunshine upon the surface of the snow§; and by Sir HUMPHRY DAVY, with coloured pieces of copper, in 1799. Six pieces of copper variously coloured, with a small portion of cerate on their under surface, were exposed on a white board to the rays of the sun, and the time of the cerate melting noted. The result was nearly the same as in Dr. FRANKLIN's experiment with pieces of coloured cloth. Sir HUMPHRY did not pursue the investigation further, though in one of his works he distinctly states it as probable, that the colour of bodies is connected with their power of absorbing heat‖.

* Count RUMFORD's Essays, vol. ii. p. 430. London, 1798.

† Philosophical Transactions, 1804, pp. 95, 96.

‡ Essay on Heat, p. 95.

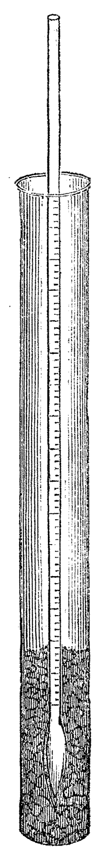
§ FRANKLIN's Works, vol. ii. p. 109. London, 1806.

‖ Elements of Chemical Philosophy, vol. i. London, 1802.

The writers on chemistry, since the date of Sir HUMPHRY DAVY's work, merely mention the subject in terms similar to his. Dr. TURNER, indeed, is of opinion, that it remains to be proved whether any effect in the absorption of non-luminous caloric can be attributed to colour*; and Dr. THOMAS THOMSON, in his late work, says, that "hitherto it has been impossible to ascertain the efficacy of hardness and softness, and of colour upon the radiation of heat†."

I am far from thinking that the experiments now to be detailed will solve all the phenomena observed where colour may be supposed to influence the results. All I maintain is, that colour exercises a powerful influence over the absorption and radiation of caloric, both luminous and non-luminous. Future experiments may determine the extent of this modifying principle, which, till now, has been doubted or denied by most of the writers who have alluded to the subject.

Fig. 1.



I. *On the Absorption of Heat by differently coloured substances.*

Previous to detailing the experiments, it may be necessary for me to describe the apparatus employed. I took a very accurate thermometer by LOVI, graduated on the tube, which was kindly lent me by Dr. CHRISTISON. The substances to be experimented upon, when of wool, silk, or cotton, were wrapped round the bulb of the thermometer, and the thermometer then placed in a glass tube about three quarters of an inch diameter, and about nine inches long. The tube was then plunged into boiling water, and the time which elapsed during the rise of the thermometer from one given point to another accurately ascertained. The thermometer in all the experiments stood at 50° before being plunged into the boiling water, and was allowed to rise to 170° FAHRENHEIT. The apparatus was, in fact, nearly the same as that used by Count RUMFORD, except that in his experiments the tube terminated in a ball to correspond with the bulb of the thermometer.

1. The first substance used was wool, variously coloured, and as

* Elements of Chemistry, 4th edition, p. 18.

† An Outline of the Sciences of Heat and Electricity, p. 147. London, 1830.

nearly as possible of the same degree of fineness. The colours used were black, dark green, scarlet, and white, thirty grains by weight of each colour.

Black wool, at 50° FAHR.,

In 30^s rose to	78°
In other 30^s rose to	102
Ditto	118
Ditto	130
Ditto	138
Ditto	145
Ditto	155
Ditto	164
Ditto	170

In 4^m 30^s the temp. rose from 50° to 170°.

Scarlet wool, at 50° FAHR.,

In 30^s rose to	74°
In other 30^s rose to	96
Ditto	112
Ditto	122
Ditto	131
Ditto	138
Ditto	146
Ditto	154
Ditto	162
Ditto	166
Ditto	170

In 5^m 30^s the temp. rose from 50° to 170°.

Dark green wool, at 50° FAHR.,

In 30^s rose to	76°
In other 30^s rose to	100
Ditto	116
Ditto	128
Ditto	138
Ditto	146
Ditto	156
Ditto	164
Ditto	167
Ditto	170

In 5^m the temp. rose from 50° to 170°.

White wool, at 50° FAHR.,

In 30^s rose to	76°
In other 30^s rose to	100
Ditto	108
Ditto	118
Ditto	128
Ditto	136
Ditto	142
Ditto	148
Ditto	154
Ditto	158
Ditto	160
Ditto	163
Ditto	165
Ditto	168
Ditto	169·5
Ditto	170

In 8^m temp. rose from 50° to 170°.

Thus it appears from the foregoing experiments that

		m	s
Black	wool rose from 50° to 170° FAHR. in	4	30
Dark green	——	5	0
Scarlet	——	5	30
White	——	8	0

2. In a similar experiment with the same colours, but with only twenty grains of each, the following were the results :—

Black wool, at 50° Fahr.,

In one minute rose to	100°
In another minute to	128
Ditto	146
Ditto	157
Ditto	164
Ditto	168
In other 35ˢ to	170

Green wool, at 50° Fahr.,

In one minute rose to	98°
In another minute to	125
Ditto	140
Ditto	153
Ditto	160
Ditto	165
Ditto	168
In other 43ˢ to	170

Scarlet wool, at 50° Fahr.,

In one minute rose to	95°
In another minute to	123
Ditto	138
Ditto	149
Ditto	158
Ditto	163·5
Ditto	167
Ditto	169·9
In other 3ˢ to	170

White wool, at 50° Fahr.,

In one minute rose to	94°
In another minute to	118
Ditto	130
Ditto	142
Ditto	154
Ditto	160
Ditto	165
Ditto	169
In other 45ˢ to	170

In this experiment the

Black wool rose from 50° to 170° Fahr. in	6ᵐ	35ˢ
Green ——	7	43
Scarlet ——	8	3
White ——	8	45

3. The next set of experiments were made with the common air thermometer, graduated to tenths of an inch in a descending series. The bulb was coated with the various colours as mentioned, and heat thrown on the ball by means of planished tin reflectors, about three inches in diameter, from a gas Argand burner. At the commencement of the experiments the coloured fluid always stood at 1°. Coated with blacking from a wax candle, and the heat reflected as mentioned, the fluid descended in a mean of four experiments to . . . . 83°

Dark brown, a mean of three experiments to	74
Orange red, ——	58
Yellow, ——	53
White, ——	45

The dark brown colouring-matter was peroxide of lead mixed with mucilage, and laid on with a hair-pencil; the orange red was common red lead; the yellow was litharge; and the white the common white lead of the shops. These colours were adopted in order to obviate the objection that might be made if the colouring substances had been of extremely different composition.

4. In another set of experiments, where the colouring-matter was laid on in a finer coating, and the flame of the burner reduced, the colours stood thus:—

Maximum descent with blackened ball	52°
———— Prussian blue	50
———— Umber brown	47
———— Green	44
———— Orange red	44
———— Yellow	39
———— White	34

The black coating was from the smoke of a wax candle; the blue from prepared Prussian blue; the brown from the common umber of the shops; the green from a mixture of Prussian blue, litharge, and a little gamboge; the red from red lead; the yellow from litharge and gamboge; and the white from the common white lead of the shops.

Though the above experiments, particularly those with the coloured wools, do not coincide exactly in minute particulars, the general result of the whole is nearly the same as to the ratio of the absorbing powers. Minute differences, in experiments made at intervals, may be easily accounted for from the various state of aggregation of the wool, and its being placed equally all round the bulb of the thermometer. The experiments with the air thermometer are not liable to the same objection, and the mean of a number of experiments made with this instrument would afford a pretty correct estimate of the absorbent powers of different colours.

These experiments decidedly show, that colour, independently of the nature of the substance employed, has a powerful influence over the absorption of caloric. They agree in a striking manner with the results of the experiments made by Dr. Franklin and Sir Humphry Davy, upon bodies of very different qualities, as is seen by the following comparison of the order of absorbing powers.

Absorption of Heat.

Franklin, Coloured Cloths.	Davy, Coloured Metal.	Stark, Coloured Wool.	Stark, Coloured ball of Thermometer.
Black.	Black.	Black.	Black.
Deep blue.	Blue.	——	Dark blue.
Lighter blue.	——	——	Brown.
Green.	Green.	Dark green.	Green.
Purple.	——	——	——
Red.	Red.	Scarlet.	Orange red.
Yellow.	Yellow.	——	Yellow.
White.	White.	White.	White.

II. *On the Radiation of Heat by differently coloured substances.*

It has been stated as a general principle, that the radiating powers of bodies in regard to heat, bear a proportion to their absorbing powers; that is to say, that the more quickly a body is heated, the more quickly does it part with its heat. On the contrary, it is known, that bodies which are the most powerful reflectors of heat, are those which, when heated, retain that heat the longest. This has been more particularly noticed with regard to the metals, in which, by diminishing the polish of the surface, it was found that their reflecting powers were much reduced, while their power of radiating or giving out heat was increased. No experiments have, so far as I know, been made to prove the influence of colour in modifying the radiation of heat, except with regard to metal balls and cylinders coated with black.

In these circumstances, it struck me that it would be important to ascertain whether colour, which exerts an influence so powerful over the absorption of heat, might not exert an equal influence over its radiation. To ascertain this point, was now the object of my investigation; and my anticipations as to the result were fully realized, as the following experiments demonstrate. If they are not so complete as could be wished, or the best that could be devised, they prove sufficiently the general principle, and may pave the way for more accurate investigations.

1. The first experiments which I made on the radiation of caloric, were with wools differently coloured. The colours were black, red, and white, of each

thirty grains weight. Having rolled each round the bulb of the thermometer, as formerly described, and placed them in the tube, it was heated in boiling water to the temperature of about 190°; and when the mercury in the thermometer began to descend, and had fallen to 180° FAHR., it was plunged into water at 45°, and the rate of cooling accurately noted. The following were the results:—

Black wool, at 180° FAHR.,	Red wool, at 180° FAHR.,	White wool, at 180° FAHR.,
In 60^{s} temp. fell to 121°	In 60^{s} temp. fell to 154°	In 60^{s} temp. fell to 158°
In other 60^{s} to 106	In other 60^{s} to 137	In other 60^{s} to 140
Ditto 95	Ditto 125	Ditto 128
Ditto 85	Ditto .... 115·5	Ditto 116
Ditto .... 79·5	Ditto 105	Ditto 107
Ditto .... 74·7	Ditto 98	Ditto 98
Ditto .... 66·7	Ditto 92	Ditto 92
Ditto .... 63·7	Ditto .... 86·5	Ditto 86
Ditto .... 61·5	Ditto 82	Ditto 82
Ditto .... 59·5	Ditto 78	Ditto 78
Ditto 58	Ditto 75	Ditto 74
Ditto .... 56·3	Ditto 72	Ditto 71
Ditto .... 55·7	Ditto .... 69·3	Ditto 68
Ditto .... 54·2	Ditto 67	Ditto .... 65·5
Ditto .... 53·5	Ditto 65	Ditto .... 63·5
Ditto .... 52·7	Ditto 63	Ditto .... 61·7
Ditto 52	Ditto .... 61·5	Ditto 59
Ditto .... 51·5	Ditto .... 59·5	Ditto .... 57·7
Ditto 51	Ditto 58	Ditto .... 56·5
Ditto .... 50·5	Ditto 56	Ditto 55
Ditto 50	Ditto 55	Ditto .... 54·2
	Ditto 54	Ditto .... 53·3
	Ditto 53	Ditto .... 52·5
	Ditto 52	Ditto .... 51·7
	Ditto 51	Ditto 51
	Ditto 50	Ditto .... 50·5
		Ditto 50

So that it appears the temperature fell in much the same ratio as it rose in the former experiments, with the same substances.

Black	wool fell from 180° to 50° FAHR. in	21^{m}	0^{s}
Red	————————————	26	0
White	————————————	27	0

Another experiment with black, red, and white wools, twenty grains of each, and with the temperature at 173°, gave the following results:—

Black wool, at 170° Fahr.,		Red wool, at 170° Fahr.,		White wool, at 170° Fahr.,	
In 60^s temp. fell to	128°	In 60^s temp. fell to	140°	In 60^s temp. fell to	140°
In other 60^s to	117	In other 60^s to	124	In other 60^s to	128
Ditto	104	Ditto	112	Ditto	115
Ditto	93	Ditto	105	Ditto	106
Ditto	86	Ditto	98	Ditto	99
Ditto	80	Ditto	89	Ditto	92
Ditto	77	Ditto	85	Ditto	89
Ditto	74	Ditto	80	Ditto	84
Ditto	71·5	Ditto	76	Ditto	80
Ditto	69·5	Ditto	73·5	Ditto	76
Ditto	67·5	Ditto	70	Ditto	74
Ditto	65·7	Ditto	68	Ditto	71
Ditto	64	Ditto	66	Ditto	69
Ditto	62·7	Ditto	64	Ditto	67
Ditto	61	Ditto	62·5	Ditto	65
In other 45^s to	60	Ditto	61	Ditto	63·5
		Ditto	60	Ditto	62
				Ditto	60·5
				In other 30^s to	60

Black wool fell from 170° to 60° Fahr. in	15^m	45^s
Red ————————	17	0
White ————————	18	30

The next experiments were made with wheat flour, coloured black, brown, yellow, and white. The black colouring-matter was lamp-black; the brown was the umber of the shops; and gamboge powder was the yellow. I took one hundred grains of each coloured flour, and placed them separately in a tube of about three quarters of an inch in diameter; then sunk the bulb of the thermometer into the middle of the flour, and heated the tube in boiling water to about 190° Fahrenheit. When the mercury began steadily to descend and arrived at 180°, I plunged the tube into water at 45°, and observed the rate of cooling. The following were the results:—

Black flour, at 180° FAHR.,

In 60^s the temp. fell to	142°
In other 60^s to	110
Ditto	91
Ditto	78
Ditto	68
Ditto	62
Ditto	57
Ditto	54
Ditto	52
In other 50^s to	50

Brown flour, at 180° FAHR.,

In 60^s the temp. fell to	142°
In other 60^s to	114
Ditto	96
Ditto	84
Ditto	74
Ditto	66
Ditto	60
Ditto	56
Ditto	54
Ditto	52
Ditto	50

Yellow flour, at 180° FAHR.,

In 60^s the temp. fell to	145°
In other 60^s to	119
Ditto	99
Ditto	85
Ditto	75
Ditto	67·5
Ditto	62
Ditto	57·5
Ditto	55
Ditto	52·5
Ditto	51
Ditto	50

White flour, at 180° FAHR.,

In 60^s temp. fell to	148°
In other 60^s to	122
Ditto	102
Ditto	88
Ditto	78
Ditto	69
Ditto	64
Ditto	58
Ditto	56
Ditto	54
Ditto	52
Ditto	50·3
In other 15^s to	50

Thus, Black flour fell from 180° to 50° FAHR. in	9^m	50^s
Brown	11	0
Yellow	12	0
White	12	15

A third set of experiments was made by coating the ball of the air-thermometer with various pigments as described; and having heated the ball till it descended to 100° on the scale, the rise of the coloured fluid was accurately noted. The results were as follows:—

Black ball, at 100° Fahr.,

(Coloured from smoke of wax candle,)

In 60^s rose to......	21°
In other 60^s rose to .	2
In other 2^s to......	1

Second Experiment.

In 60^s rose to......	20°
In other 60^s to	2
In other 3^s to......	1

Brown ball, at 100° Fahr.,

(Coloured with peroxide of lead,)

In 60^s rose to......	27°
In other 60^s to	6
In other 40^s to	1

Second Experiment.

In 60^s rose to......	28°
In other 60^s to	6
In other 40^s to	1

Orange-red ball, at 100° Fahr.,

(Coloured with red lead,)

In 60^s rose to......	34°
In other 60^s to	12
Ditto	3
In other 45^s to	1

Second Experiment.

In 60^s rose to......	34°
In other 60^s to	13
Ditto	3
In other 44^s to	1

Yellow ball, at 100° Fahr.,

(Coloured with litharge and gamboge,)

In 60^s rose to	33°
In other 60^s to..............	13
Ditto..................	5
Ditto..................	2
In other 28^s to..............	1

Second Experiment.

In 60^s rose to	34°
In other 60^s to..............	14
Ditto..................	6
Ditto..................	2
In other 30^s to..............	1

White ball, at 100° Fahr.,

(Coloured with white lead,)

In 60^s rose to	40°
In other 60^s to..............	21
Ditto..................	9
Ditto..................	6
Ditto..................	2
In other 50^s to..............	1

Second Experiment.

In 60^s rose to	41°
In other 60^s to..............	21
Ditto..................	9·5
Ditto..................	7
Ditto..................	2·5
In other 51^s to..............	1

These experiments demonstrate that differently coloured substances possess a specific influence on the absorption of heat or caloric, both luminous and non-luminous; and that they give off their caloric in the same ratio as they absorb it.

The experiments may be varied to any extent, by using different substances; and even water in coloured vessels cools more or less quickly, according to the colour of the vessel in which it is held. For instance, to ascertain this, I filled glass balls about an inch and a quarter in diameter with water at 120° Fahr., and placed a thermometer in the fluid. The time which elapsed during the fall of the mercury through 25° was accurately noted, and the results were,

that the ball coated with Prussian blue fell through that interval in seventeen minutes; the ball coated with orange red in eighteen minutes; and that coated with white in nineteen minutes. The temperature of the air in the room was 50°.

The demonstration of the influence of colour on the absorption and radiation of caloric, may tend to open up new views of the economy of Nature, and perhaps suggest useful improvements in the management and adaptation of heat. Dr. Franklin*, who never lost sight of practical utility in his scientific investigations, from the result of his experiments with coloured cloths on the absorption of heat, drew the conclusion, "that black clothes are not so fit to wear in a hot sunny climate or season as white ones, because in such clothes the body is more heated by the sun when we walk abroad and are at the same time heated by the exercise; which double heat is apt to bring on putrid, dangerous fevers;" that soldiers and seamen in tropical climates should have a white uniform; that white hats should be generally worn in summer; and that garden walls for fruit trees would absorb more heat from being blackened.

Count Rumford and Sir Everard Home, on the contrary, come to a conclusion entirely the reverse of this. The Count asserts, that if he were called upon to live in a very warm climate, he would blacken his skin or wear a black shirt; and Sir Everard, from direct experiments on himself and on a negro's skin, lays it down as evident, "that the power of the sun's rays to scorch the skins of animals is destroyed when applied to a dark surface, although the absolute heat, in consequence of the absorption of the rays, is greater†." Sir Humphry Davy explains this fact by saying, "that the radiant heat in the sun's rays is converted into sensible heat." With all deference to the opinion of this great man, it by no means explains why the surface of the skin was kept comparatively cool. From the result of the experiments detailed, it is evident, that if a black surface absorbs caloric in greatest quantity, it also gives it out in the same proportion; and thus a circulation of heat is as it were established, calculated to promote the insensible perspiration, and to keep the body cool. This view is confirmed by the observed fact of the stronger odour exhaled by the bodies of black people.

* Dr. Franklin's Works, vol. ii. p. 109. London, 1806.

† Philosophical Transactions, 1821, p. 6.

The different shades of colour by which races of men inhabiting different climates are distinguished, equally possess, there is reason to believe, the quality of modifying the individual temperature, and keeping it at the proper mean. This adaptation of colour may perhaps be traced in the inhabitants of every degree of latitude, and be found to correspond with the causes which limit the range of plants and animals. The effect of exposure to the sun in our own country in warm seasons, is temporarily to change the colour of the parts submitted to its influence, and to render them less susceptible of injury from the heating rays.

The influence of colour as modifying the effects of heat, is also strikingly illustrated in other classes of the animal kingdom. The quadrupeds, for instance, which pass the winter in northern latitudes, besides the additional protection from cold they receive in the growth of downy fur, change their colour on the approach of the cold season. The furs of various hues which form their summer dress are thrown off, and a white covering takes its place. Hence the white foxes, the white hares, and the ermine of the arctic regions. Even in more temperate climates, and in our own country, the hare in severe winters often acquires a white fur; and the stoat, or ermine, is found with its summer dress more or less exchanged for a winter clothing of pure white. Some writers on natural history state these changes as means of protection to the animals from their enemies, by assimilating their colour to the winter snow. Without denying that this may be one cause for the periodical change of colour, I am rather disposed to consider it as accommodating the animal to the changes of season it undergoes. The white winter coating, as is evident from the experiments detailed, does not throw off heat so rapidly as any of the other colours; and hence its use in preserving the animal temperature.

The feathered tribes which inhabit northern latitudes afford still more remarkable instances of the adaptation of colour to the changes of temperature. The summer dress of many families is so different from their winter plumage as to have led many ornithologists to multiply species, as the animal was described in its winter or summer plumage. The ptarmigan is a familiar example. Mr. Selby remarks, that "the black deep ochreous yellow plumage of the ptarmigan in spring and summer gradually gives place to a greyish white; the black spots become broken and assume the appearance of zigzag lines

and specks. These again, as the season advances, give place to the pure immaculate plumage which distinguishes both sexes in winter*."

The display of colours in the plumage of the birds of tropical climates is also in strict accordance with the observed facts of the influence of colour over the absorption and radiation of heat. The metallic reflexions and polished surface of the whole family of humming-birds is admirably suited to their habits; and the colours of the wings of the Lepidoptera, in the class of insects, there is little doubt, serve some similar purpose, in maintaining the temperature of the animals at the proper mean. In proportion to the diminution of temperature and the distance from the equator, a corresponding dilution of colour in animals takes place, till in temperate countries it is almost uniformly of a sober gray. In the arctic regions all colour except white and black disappears,—modifications of which, with very little variety of other colours, form the summer and winter clothing of most of the northern tribes of birds.

In the vegetable kingdom, I am disposed to believe that the colours of the petals of flowers serve some useful purpose in regard to preserving the temperature of the parts necessary for reproduction at the proper mean; and that the varied pencilling of Nature has thus an object beyond merely pleasing the eye. In this view, the quality of colour, so widely extended and so varied and blended in every class of natural bodies, acquires a further interest in addition to its ministering to the pleasures of sight, and affords a new instance of that benevolence and wisdom by which all the arrangements of matter are calculated to excite and gratify the mind directed to their investigation.

Even in the inorganic portion of Nature, and in northern climates, the portion of heat imbibed by the soil during a short summer is prevented from escaping by the covering of snow which falls in the beginning of winter; and thus the temperature necessary for the scanty vegetation is kept up. By this white covering vegetables are enabled to sustain a lengthened torpidity without suffering from the injurious effects of frost; and the ground is preserved from partial alternations of temperature, till the influence of the sun at once converts the northern winter into summer without the intervention of spring.

* Selby's Illustrations of British Ornithology, Part I. p. 312.

On the influence of Colour on the deposition of Dew.

As connected with the preceding investigations, it may be mentioned, that I had projected a train of experiments to ascertain the proportions in which dew was deposited on variously coloured substances. Dr. WELLS found the deposition of dew influenced by the radiating power of the substance employed; but neither he nor any of the philosophers who have treated of the subject seem to have been aware of the modifying effects of colour on the absorption and radiation of Heat. My avocations have hitherto prevented me from following out these experiments; but to show that the influence of colour may be extended to moisture, and of course to Dew, I shall give from my notes the result of two experiments made to ascertain this point.

January 16, 1833.—I exposed last night (the temperature ranging from 28° to 30°, and with a dense fog,) ten grains of black wool, the same quantity of scarlet wool, and an equal weight of white wool, on a black board, which was placed on the leads on the top of the house. When taken in this morning and carefully weighed, the

Black wool had gained	32 grains.
Scarlet wool	25 ——
White wool	20 ——

deposited on the wool in the form of hoar frost.

A few nights afterwards, after a slight thaw, and when towards night the temperature fell to 31°, I again exposed four colours of wool, ten grains of each, in the same manner. By next morning the

Black wool had gained . . .	10 grains.
Dark green	$9\frac{5}{10}$ ——
Scarlet	6 ——
White	5 ——

Dr. WELLS had indeed made experiments on the deposition of dew with equal quantities of black and white wool; and in four out of five experiments, the black wool was found to have acquired a little more dew than the white; "whence," says he, "I concluded that it had also radiated a little more heat. But I afterwards remarked, that the white wool was somewhat coarser than

the black, which might have occasioned the difference of their attraction for dew." On another night he made an experiment with pasteboard covered with white paper, and pasteboard covered with paper blackened with ink. "At daylight," says he, "I observed hoar frost upon both pieces, but the black seemed to have a greater quantity than the white*."

These facts, it might have been supposed, would have led Dr. Wells to further experiments with different colours. But the reverse was the case. He quotes Mr. Leslie as to the hopelessness of success, without making a further attempt; "since a black body almost always differs from a white in one or more chemical properties, and this difference may alone be sufficient to occasion a diversity in their powers of radiating heat."

PART II.

ON THE INFLUENCE OF COLOUR ON ODOURS.

If the influence of colour over heat attracted but little the attention of philosophers employed in the investigation of the absorbing and radiating powers of different substances, even when presented to their notice in anomalous facts, which could not easily be explained on any other principle, it is not to be wondered at, that the apparently far less appreciable influence of Colour on Odours should have totally escaped notice. In point of fact, I am not aware that the subject has hitherto been investigated, and know of no recorded facts in which the influence of colour over odours has been pointed out. In attempting to show from experiment that the colour of bodies in imbibing odours is correlative with the power of colour over the absorption and radiation of heat, I state a fact which, though new to science, is in admirable correspondence with the known properties of light and heat. And though I may not be able, from the nature of the substances subjected to experiment, absolutely to determine the amount of this connexion, I trust my imperfect investigations may form the basis of new and better devised experiments, by directing the attention of men of science to this hitherto untrodden field of inquiry.

* Wells on Dew, p. 106. London, 1814.

My attention was first directed to the subject of odours, as connected with colour, during my attendance at the anatomical rooms in the winter session 1830–1831. During the earlier part of that winter I generally wore a light olive-coloured dress; but happening one day to attend the rooms in black clothes, I was not a little struck by the almost intolerable smell they had acquired. The smell was so very strong as to be remarked even by the family at home, and it was recognised on the same piece of dress for several days. No odour to the same extent had been remarked in the lighter-coloured clothes. The fetid smell which they more or less acquired in the atmosphere of the rooms was comparatively trifling, and slight exposure to the air alone was necessary to deprive them of the odour which they had thus contracted.

This circumstance led me to begin a series of experiments, to ascertain, if possible, why different cloths of nearly the same texture, but not of the same colour, should attract odours in proportions so very different. The result was, as I had ventured to conjecture, that the colour of bodies, independent of the nature of the substance, modifies in a striking manner the capability of surfaces for imbibing and giving out odours.

1. I inclosed black and white wool, ten grains of each, in a vessel with a small piece of camphor, and kept it carefully secluded from the light. When examined six hours afterwards, it was at once evident to the sense of smell that the black wool had attracted more of the odorous particles than the white wool, though neither had gained any appreciable weight.

2. I took equal weights of black and white wool, and put them in a small drawer along with a piece of assafœtida; in twenty-four hours the black wool had contracted a strong odour of the gum, while in the white wool, the smell was scarcely perceptible.

3. To try the effect of odours upon a vegetable substance, I took equal quantities of black and white cotton wool, and inclosed them with assafœtida. Two similar quantities were at the same time exposed to the emanations of camphor in another drawer. In both the black-coloured cotton had attracted the greatest quantity of odorous particles, as palpably evidenced by the smell.

These experiments were made in the month of April 1831; but it was not till August following that I had an opportunity of extending the investigation to other colours.

4. I inclosed equal weights of black, red, and white wool, in a drawer with assafœtida; and similar quantities of these coloured wools in another drawer with camphor. The result was as before. The black in both experiments had attracted by far the greatest quantity of odorous particles, as evidenced to smell; the red next followed in point of intensity of smell; and the white, so far as could be judged, had attracted least of the odour.

5. The same experiments were tried on cotton of similar colours, and with the same results.

Circumstances prevented me from resuming these investigations till the summer of 1832, when I repeated the experiments with a greater variety of coloured substances, in wool, cotton, and silk, and satisfied not only myself but many of my friends, that odour was attracted nearly in the same ratio as caloric, by coloured substances. The experiments were conducted in the same manner as the preceding.

6. I inclosed six different-coloured wools, an equal weight of each, viz. black, blue, green, red, yellow, and white, with assafœtida. They were ranged circularly round the odorous body, without touching it or one another, and were then covered over and excluded from the light. At the end of twenty-four hours they were examined. The black was found to have much the strongest smell of assafœtida; the blue the next; after that the red, and then the green; the yellow had but little smell, and the white scarcely any.

7. A similar experiment, using camphor instead of assafœtida, afforded precisely the same results.

8. Various coloured cottons were treated in the same manner. In all these the smell was invariably found to be of corresponding intensity, according to the colour, as in the wools.

9. Silks of different colours gave the same results.

10. I next endeavoured to ascertain the comparative power of vegetable and animal substances, so far as regards their influence over odours. This was a much more delicate point to ascertain with sufficient accuracy, and free from fallacy, as it was difficult to obtain wool of the same degree of fineness as cotton, the substances I generally preferred for these experiments. I first inclosed equal weights of black and white wool, and black and white cotton,

with camphor. After twenty-four hours, the black wool had acquired a stronger smell than the cotton of similar colour; the white wool had also taken up more of the odorous particles than the white cotton, though the odour in both was very feeble.

11. When assafœtida was used in a similar experiment, the odour was much more distinguishable, and it could at once be distinguished by smell, that the wool had taken up much more of the odour than the cotton. Indeed, from many experiments I have made to ascertain this fact, wool appears to have a peculiar attraction for fetid odours. For instance, if, after having allowed wool to lie in contact with camphor for some time, it be afterwards placed, even for a very few hours, near a minute portion of sulphuret of barium (which, it is well known, exhales copiously the fetid odour of sulphuretted hydrogen,) it quickly loses the camphorous smell, and acquires and even retains in considerable intensity the fetid smell of the sulphuret.

It is proper to mention, that in most of these experiments I did not trust to my own olfactory organs alone. All the members of the family, and several of my friends, have lent their aid to distinguish between the different intensities of the odour which each substance had attracted; and though only a few experiments are here detailed, similar ones have been many times performed, with various other odorous substances. The whole of these in their general results seemed to establish the fact, that the colour of substances exerted a peculiar influence over the absorption of odours.

In all these experiments, however, reliance had to be placed upon one sense alone, viz. that of smell, as none of the substances employed had gained any appreciable weight. I was therefore desirous, that, if possible, at least one experiment should be devised, which would show, by the evidence of actual increase of weight, that one colour invariably attracted more of any odorous substance than another; and upon considering the various odorous substances which could be easily volatilized without change, and whose odour was inseparable from the substance, I fixed upon camphor as the one best suited to my purpose. In an experiment of this nature, it was necessary that the camphor should be volatilized or converted into vapour, and that the coloured substances should be so placed as to come in contact with the camphor while in that state. It was therefore of the first importance to prevent currents of air

within the vessel in which the experiment was conducted; and with this view I used a funnel-shaped vessel of tin plate, open at the top and bottom, of the form represented in fig. 2. This rested on a plate of sheet iron, in the centre of which the camphor to be volatilized was placed. The coloured substances, after being accurately weighed, were supported on a bent wire (as shown in the section fig. 3.), and introduced through the upper aperture. This was then covered over with a plate of glass. Heat was now applied gently to volatilize the camphor; and when the heat was withdrawn and the apparatus cool, the coloured substances were again accurately weighed, and the difference in weight noted down.

Fig. 2.

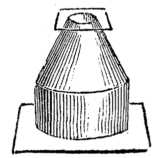
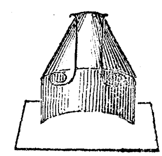


Fig. 3.



Proceeding on this plan, I arrived at the most satisfactory and conclusive results. The deposition of the camphor in various proportions on the coloured substances submitted to experiment, offered evidence of the particular attraction of colours for odours, resting on ocular demonstration; and when to this is added the evidence arising from a positive increase of weight, as ascertained by the balance, the conclusions previously drawn from the sense of smell are confirmed in a singular and very satisfactory manner. I have in this mode repeated all the former experiments with differently coloured substances; but shall here only detail a few, as sufficient to show the general results.

1. I took ten grains of white, and the same quantity of black wool, and having suspended them in the manner stated, vaporized the camphor. When the apparatus cooled, I found on weighing the wool, that the white had gained $1\frac{5}{10}$ grain in weight, and the black $1\frac{8}{10}$ grain.

2. In a similar experiment, but using three colours of wool, white, red, and black, I found the white wool had gained $\frac{3}{10}$ths of a grain; the red $\frac{8}{10}$ths; and the black $1\frac{4}{10}$ grain.

3. In another, where the heat was applied for about ten seconds, the white had gained no appreciable weight, and but little smell; the red had gained $\frac{1}{20}$th of a grain; while the black had acquired $\frac{2}{10}$ths of a grain.

4. In an experiment with black, red, green, and white wool, the results were:—

Black gained	$\frac{3}{10}$ grain.
Red	$\frac{2}{10}$ ——

Green gained	$\frac{2 \cdot 5}{10}$	——
White	$\frac{1}{10}$	——

5. In an experiment with wools of nearly the same fineness, coloured black, blue, red, green, and white, ten grains of each, exposed to the vapour of camphor, the result stood thus:—

Black gained	$1\frac{2}{10}$	grain.
Dark blue	$1\frac{2}{10}$	——
Scarlet red	1	——
Dark green	1	——
White	$\frac{7}{10}$	——

In repeating this experiment the dark green was $\frac{7}{10}$, while the red was only $\frac{6}{10}$; the others in the order as before.

I now varied the experiment by employing square pieces of card of equal size, coloured with different preparations of lead. This was done with the view of ascertaining whether smooth surfaces of equal density, and coloured as nearly as possible with matter of the same nature, would absorb odorous particles with the same facility as loose portions of wool. The colours were mixed up with a solution of gum arabic, and laid on the cards as equally as possible with a camel-hair pencil.

6. Pieces of card of equal size being coloured as mentioned, with various preparations of lead, namely, red, brown, yellow, and white, and previously weighed, were exposed to the vapour of camphor in the vessel before described. After exposure for some time, and when cool, it appeared on weighing that the

Red had gained	1	grain.
Brown	$\frac{9}{10}$	——
Yellow	$\frac{5}{10}$	——
White	a trace.	

The whole of the upper surfaces of the red and brown cards were thickly covered with a fine light downy deposit of camphor. The white card had an extremely fine deposit on its surface, but inappreciable by the balance, which turns with the fiftieth part of a grain.

7. Another experiment with cards, coloured black, red, brown, yellow, and white, exposed to the vapour of camphor, gave the following results:—

Black gained	1	grain.
Red	$\frac{9}{10}$	——
Brown	$\frac{7}{10}$	——
Yellow	$\frac{5}{10}$	——
White	$\frac{4}{10}$	——

8. In a similar experiment with cards coloured black, dark blue, dark brown, orange red, and white, the attractive powers were as follows:—

Black gained	$\frac{9}{10}$	grain.
Dark blue	$\frac{8}{10}$	——
Dark brown	$\frac{4}{10}$	——
Orange red	$\frac{3}{10}$	——
White	$\frac{1}{10}$	——

In all these experiments it was invariably found that the black attracted most; the blue next; then followed the red and green; and after these the yellow and white. The heat was never continued so long as to warm the apparatus, else the whole camphor would have been driven off. Neither was such a quantity of camphor used as would have given a thick coating to the wool employed, as then the attraction of the coloured surfaces might have been diminished.

1. The next set of experiments were intended to ascertain the comparative attraction of animal and vegetable substances. The first of these was upon equal weights of black wool and black silk, (ten grains,) exposed to the vapour of camphor in the manner already stated. The black wool gained $1\frac{5}{10}$ grain, and the black silk $1\frac{7}{10}$ grain. From this experiment it would appear that of these two animal substances, silk possesses the greatest attraction for odours.

2. In equal weights of white wool and white cotton, the cotton had gained $\frac{3}{10}$ths of a grain, and the wool $\frac{4}{10}$ths.

3. In another experiment with white silk, white wool, and white cotton, ten grains of each, the result was:—

Silk had gained	$3\frac{5}{10}$	grains.
Wool	$2\frac{4}{10}$	——
Cotton	$2\frac{2}{10}$	——

4. In a similar experiment with the usual weight of the same articles,

Silk had gained	$1\frac{4}{10}$	grain.
Wool	$\frac{5}{10}$	——
Cotton	$\frac{4}{10}$	——

5. Another experiment, in which black silk, black wool, and black cotton were exposed, in equal quantities of the usual weight, to the vapour of camphor, as before described, gave this result:—

Black silk had gained	$\frac{2}{10}$	grain.
Black wool	$\frac{1}{10}$	——
Black cotton	$\frac{1}{20}$	——

6. An experiment with white silk, white wool, white cotton, and white card, each weighing ten grains, and exposed as before, gave the following results:—

White silk had gained	$1\frac{9}{10}$	grain.
White wool	$1\frac{1}{10}$	——
White cotton	1	——
White card	$\frac{4}{10}$	——

The last experiments tend to show that different substances attract odours in different proportions, and this independent of the texture or fineness of the substance employed. Wool, though generally coarser in the filament than cotton, has yet a greater attraction for odours; and silk more than wool. The general conclusion would appear to be, that animal substances have a greater attraction for odours than vegetable matters; and that all these have their power much increased by their greater darkness or intensity of colour. These experiments seem also to establish, that the absorption of odours by coloured substances is regulated by the same law which governs the absorption of light and heat. The analogy goes still further; for in other experiments made with a view to ascertain this point, I invariably found, that the power of colour in radiating or giving out odours, was in strict relation to the radiation of heat in similar circumstances. My first experiments on this branch were with differently coloured wools, inclosed for a certain time in a drawer along with assafœtida and camphor, and afterwards exposed for a specific period to the action of the air. Though one can easily judge by the sense

of smell alone the different intensities which these articles have acquired immediately on being taken out of the drawer, yet, after exposure for some time to the air, the difference of intensity is much more difficult to be perceived. In general it seemed to me, that the whole of the substances lost their sensible odour in nearly the same space of time, though the odorous particles given out by the black were of course much greater in quantity than in the others.

To demonstrate this, I took pieces of card coloured, as before, black, dark blue, brown, orangered, and white, and after having exposed them to the vapour of camphor, in the usual manner, they were taken out of the vessel, weighed, and left in the apartment for twenty-four hours. Upon carefully re-weighing the cards at the end of this period, it was found that the black had lost one grain; the blue nearly as much; the brown $\frac{9}{10}$ths of a grain; the red $\frac{8}{10}$ths; and the white $\frac{5}{10}$ths of a grain. In about six hours after this the black and blue had completely lost their camphor; the brown and red had the merest trace, inappreciable to a delicate balance; while the white still retained about $\frac{1}{30}$th of a grain.

In another experiment with cards coloured dark blue, dark brown, orange red, yellow, and white, they had gained in weight, after exposure to the vapour of camphor,

Dark blue	$\frac{9}{10}$ grain.
Dark brown	$\frac{8}{10}$ ——
Orange red	$\frac{6}{10}$ ——
Yellow	$\frac{5}{10}$ ——
White	$\frac{4}{10}$ ——

After lying in the apartment for twenty-four hours, the cards were again carefully weighed, when the camphor remaining was found to be on the

Dark blue	$\frac{1}{30}$ grain.
Dark brown	$\frac{1}{10}$ ——
Orange red	$\frac{2}{10}$ ——
Yellow	$\frac{1}{10}$ ——
White	$\frac{3}{10}$ ——

Hence in the same space of time the loss in each was,

Dark blue	$\frac{26}{30}$ grain.
Dark brown	$\frac{21}{30}$ ——
Orange red	$\frac{12}{30}$ ——
Yellow	$\frac{12}{30}$ ——
White	$\frac{3}{30}$ ——

The influence of coloured surfaces upon the absorption and emission of odours, having, I trust, been satisfactorily shown, it only remains for me to state shortly some of the practical conclusions which may be drawn from the experiments detailed.

If it be thus certain that odorous emanations have not only a particular affinity for different substances, but that the colour of those substances materially affects their absorbing or radiating quality; the knowledge of these facts may afford useful hints for the preservation of the general health during the prevalence of contagious or epidemic diseases. From their minute division and vast range of action, latent poisonous exhalations or effluvia, inappreciable by the balance, may, no doubt, exist to dangerous extent without being evident to the sense of smell. But in most cases it will be found, that, when contagious diseases prevail to such extent, the emanations from the sick will, if attended to, give the surest indications of the contamination of the surrounding air.

Experience has sufficiently proved, that emanations, once generated in, or communicated to, the human body, may be conveyed from one individual to another, and even through the medium of clothing or merchandize from one place to another. This has been particularly observed in plague; and hence in countries where this disease is liable to occur or be imported, the institution of quarantine establishments, to prevent personal intercourse or the dispersion of goods till a certain number of days have elapsed, during which the disease, if existing, should appear;—articles of merchandize and clothing being at the same time purified by exposure to the air, or fumigated. Though this transport of disease has been more particularly observed in plague, yet instances of the same nature have occurred in other diseases, more particularly small-pox, and more recently, it has by many been supposed, cholera.

It is unnecessary to detail here the means of purifying infected goods, or fumigating the apartments of those who have been known or suspected to labour under diseases supposed to be communicated by contagious effluvia. It is sufficient to state, that exposure to a high temperature, fumigations with chlorine and sulphur, and free exposure to the air, are found amply sufficient for the first; and apartments are now generally recommended to be purified with chlorine, and washed with caustic lime. As to fumigation with chlorine, it cannot be denied that this will destroy the animal effluvia floating in the air exposed to its action. But unless this fumigation be frequently repeated, it can have but little effect, as the walls and furniture will be constantly contaminating the air by giving out the deleterious particles which they had previously absorbed. Lime-washing has generally been supposed to act in the same manner as fumigations, viz. by destroying the contagious emanations; but from the experiments of GUYTON MORVEAU, it would seem, that caustic lime, and indeed lime in any state, has no such effect. It merely absorbs the gases which disguise the odour, but neither changes its deleterious properties nor alters its real smell. He therefore disregards lime-washing, except as a general mode of cleaning walls, and attributes no other beneficial effect to it than as contributing to cleanliness.

The results of my investigations have led me to form a very different opinion. It is to white-washing that I should attribute much of the good effects that have been observed to follow the purifying means generally employed. In such cases I should trust more to white-washing the walls, personal cleanliness, and free ventilation, for destroying or diminishing the effects of supposed pestilential or hurtful effluvia, than to any other measures. Acid and other fumigations, except chlorine, only disguise, but do not destroy the property of animal effluvia to produce disease.

In the late epidemic cholera here, it is well known, that this disease first broke out in the village of Water-of-Leith, situated a little to the north-west of Edinburgh, and lying on both sides of the stream of the same name. Many of the inhabitants were seized with the disease and fell victims to its severity. If a damp and low situation, with accumulated filth of all kinds, render disease more fatal, this was certainly a place likely to suffer severely, and at first it did so. But the Board of Health, with that promptitude, for which they were

distinguished, quickly got the filth, so far as practicable, removed, the houses fumigated, and the walls white-washed outside and inside. By these means the disease seemed at once to be arrested; its virulence was much abated, and it gradually declined. The fumigations in this case could only act upon the deleterious emanations in the air at the time; but unless constantly renewed could not affect the fresh emanations generated from those labouring under the disease. The necessary ventilation must also have speedily carried off the chlorine. The white-washing, on the other hand, although it had no specific action on the contagious effluvium, yet, by constantly presenting a reflecting surface, prevented the absorption of the emanations by the walls, and thus tended, with moderate ventilation, to keep the air of the apartments pure. Dirty dark-coloured walls, on the contrary, would readily, as has been demonstrated, absorb noxious odours, and as soon as the effect of the fumigation was over, gradually give them out again.

The good effects of white-washing appeared strikingly in another instance at this particular time; for I venture to assert, that, if human means had any influence over this disease, Edinburgh owes much of the mildness of its attack to the white-washing of its steep and narrow lanes and closes, the walls of the common stairs, and most of the hovels inhabited by the lowest classes of the community, and not to the partial fumigations and sprinkling with chloride of lime, which the first breath of wind carried off. The whiteness of the walls prevented them from absorbing the deleterious emanations, and the currents of air were thus enabled to sweep them away, before they had accumulated to such a degree as to become an active source of disease.

Next, therefore, to keeping the walls of hospitals, prisons, or apartments occupied by a number of individuals, of a white colour, I should suggest that the bedsteads, tables and seats should be painted white, and that the dress of the nurses and hospital attendants should be of a light colour. A regulation of this kind would possess the double advantage of enabling cleanliness to be enforced, at the same time that it presented the least absorbent surface to the emanations of disease.

On the same principle it would appear that physicians and others, by dressing in black, have unluckily chosen the colour of all others most absorbent of odorous exhalations, and of course the most dangerous to themselves and

patients. Facts have been mentioned which make it next to certain, that contagious disease may be communicated to a third person through the medium of one who has been exposed to contagion, but himself not affected*; and indeed the circumstance of infectious effluvia being capable of being carried by medical men from one patient to another, I should conceive one of the means by which such diseases are often propagated, in the ill-ventilated and dirty habitations of the poor exposed to their influence.

Even in my own very limited experience I think I have observed some melancholy instances of the effect of black dress in absorbing the hurtful emanations of fever patients in a public hospital; and many facts are incidentally related by medical writers, and referred to other causes, which I should not hesitate to ascribe chiefly to exposure of this nature. Not to mention individual cases, in the sessions held at Oxford in July 1577, "there arose amidst the people such a damp that almost all were smothered†." Lord BACON attributes this effect to the "smell of the gaol, where the prisoners have been close and nastily kept," and mentions it having occurred twice or thrice in his time, when both the judges that sat upon the trial, and numbers of those who attended the business, or were present, sickened or died‡." A similar occurrence, related by Sir JOHN PRINGLE, happened at the Old Bailey sessions in 1750, when four of the judges were attacked and died, together with two or three of the counsel, one of the under sheriffs, several of the jury, and others present, to the amount of above forty in the whole§. My explanation of the peculiar fatality of these emanations to the judges, counsel, and jurors, was the attraction of their official black for the putrid effluvium, as Sir JOHN calls it; and the escape of two of the judges who sat on one side of the LORD MAYOR, to the current of air in the room not sending the baneful odours in their direction.

* See Treatise on the Epidemic Puerperal Fever of Aberdeen, by ALEXANDER GORDON, M.D. London, 1795.

† STOW's Chronicle.

‡ PRINGLE's Observations on Diseases of the Army, p. 296.

§ Ibid. p. 297.