those mentioned last year being still alive. One of my nests of *Formica fusca* was brought from the woods in December 1874; it then contained two queens, both of which are now still alive. I am disposed to think that some of the workers now in the nest were among those originally captured, the mortality after the first few weeks having been but small. This, of course, I cannot prove. The queens, however, are certainly more than seven, and probably more than eight, years old. In the following nests, viz. another nest of *F. fusca*, which I brought in on the 6th June 1875, and one of *Lasius niger* on the 30th November 1875, there were no queens; and, as already mentioned, no workers have been produced. Those now living are therefore the original ones; and they must be between six and seven years old.

I had also some workers of *Lasius niger* which I began to observe on the 6th July 1875; the last of these died on June 15th, 1881. Lastly, some of *Formica cinerea* which I began to observe on the 29th November 1875, lived till the ants in this nest died off somewhat rapidly, the last on July 23, 1881. There were no queens in either of these nests; these workers therefore must have been more than 6 years old.

On the Sense of Color among some of the Lower Animals.

By Sir John Lubbock, Bart., M.P., D.C.L., LL.D., F.R.S., President Linn. Soc.

[Read November 17, 1881.]

As I have already mentioned in a previous communication* M. Paul Bert† has made some very interesting experiments on a small freshwater crustacean belonging to the genus *Daphnia*, from which he concludes that they perceive all the colors known to us, being, however, especially sensitive to the yellow and green, and that their limits of vision are the same as ours.

Nay, as I have stated (*loc. cit.*), he even goes further than this, and feels justified in concluding, from the experience of two species—Man and *Daphnia*—that the limits of vision would be the same in all cases.

* Journ. Linn. Soc. vol. xv. p. 376 (No. 87).

† Archiv. de Physiol. 1869, p. 547.

His words are:—

A. "Tous les animaux voient les rayons spectraux que nous voyons."

B. "Ils ne voient aucun de ceux que nous ne voyons pas."

C. "Dans l'étendue de la région visible, les différences entre les pouvoirs éclairants des différents rayons colorés sont les mêmes pour eux et pour nous."

He also adds:—"Puisque les limites de visibilité semblent être les mêmes pour les animaux et pour nous, ne trouvons-nous pas là une raison de plus pour supposer que le rôle des milieux de l'œil est tout à fait secondaire, et que la visibilité tient à l'impressionnabilité de l'appareil nerveux lui-même?"

These generalizations would seem to rest on a very narrow foundation. I have already attempted to show that the conclusion does not appear to hold good in the case of ants; and I determined therefore to make some experiments myself on Daphnias, the results of which are embodied in the present communication.

Prof. Dewar was kind enough again to arrange for me a spectrum, which, by means of a mirror, was thrown onto the floor. I then placed some Daphnias in a wooden trough 14 inches by 4 inches, and divided by cross partitions of glass into divisions, so that I could isolate the parts illuminated by the different colored rays. The two ends of the trough extended somewhat beyond the visible spectrum. I then placed fifty specimens of *Daphnia pulex* in the trough, removing the glass partitions so that they could circulate freely from one end of the trough to the other. Then, after scattering them equally through the water, I exposed them to the light for ten minutes, after which I inserted the glass partitions, and then counted the Daphnias in each division. The results were as follows:—

Number of Daphnias.

	Beyond the red.	In the red and yellow.	In the greenish yellow and green.	In the blue.	In the violet.	Beyond the violet.
Obs. 1. ...	0	20	28	2	0	0
„ 2. ...	1	21	25	3	0	0
„ 3. ...	2	21	24	3	0	0
„ 4. ...	1	19	29	1	0	0
„ 5. ...	0	20	27	3	0	0
	4	101	133	12	0	0

I may add that the blue and violet divisions were naturally longer than the red and green.

May 25.—Tried again the same arrangement, but separating the yellow, and giving the Daphnias the choice between red, yellow, green, blue, violet, and dark:—

	Dark.	Violet.	Blue.	Green.	Yellow.	Red.
Exp. 1.	0	0	3	39	5	3
„ 2.	0	1	2	37	7	3
„ 3.	0	0	4	31	10	5
„ 4.	0	1	5	30	8	6
„ 5.	0	1	4	33	6	6
	0	3	18	170	36	23

Of course it must be remembered that the yellow band is much narrower than the green. I reckoned as yellow a width of $\frac{3}{4}$ inch, and the width of the green 2 inches.

Again

	Dark.	Violet.	Blue.	Green.	Yellow.	Red.
Exp. 1.	0	0	4	30	6	10
„ 2.	0	1	3	25	8	13
„ 3.	0	0	2	24	9	15
„ 4.	1	0	3	25	8	13
„ 5.	0	1	2	24	7	16
	1	2	14	128	38	67

M. Paul Bert observes (*l. c.*) that in his experiments the Daphnias followed exactly the brilliance of the light. It will be observed, however, that in my experiments this was not the case—as there were more Daphnias in proportion, as well as absolutely in the green, although the yellow is the brightest portion of the spectrum.

I then so arranged the trough that the yellow fell in the middle of one of the divisions. The result was:—

Number of Daphnias.

	Ultra-red and lower red.	Upper edge of red, yellow, and lower green.	Greenish blue and blue.	Violet.	Ultra-violet.
Exp. 1.	8	38	4	0	0
„ 2.	9	36	5	0	0
„ 3.	8	39	3	0	0

May 18.—In order to test the limits of vision at the red end of the spectrum, I used the same arrangement as before, placing the trough so that the extreme division was in the ultra-red, and the second in the red. I then placed 60 Daphnias in the ultra-red. After five minutes' exposure I counted them. There were in the

	Red.	Ultra-red.
Exp. 1.	54	5
„ 2.	56	4

I now gave them four divisions—dark, red, ultra-red, and dark gain. The numbers were :—

	Dark.	Red.	Ultra-red.	Dark.
Exp. 1.	5	47	6	2
„ 2.	9	41	7	3

I then shut them off from all the colors excepting red, giving them only the option between red and ultra-red :—

	Red.	Ultra-red.
Exp. 1.	46	4
„ 2.	47	3
„ 3.	44	6

I then left them access to a division on the other side of the red, which, however, I darkened by interposing a piece of wood. This enabled me better to compare the ultra-red rays with a really dark space :—

	Dark.	Red.	Ultra-red.
Exp. 1.	4	43	3
„ 2.	3	45	2

Certainly, therefore, their limits of vision at the red end of the spectrum seen approximately to coincide with ours.

I then proceeded to examine their behaviour with reference to the other end of the spectrum.

I then shut them off from all the rays except the blue, violet, and ultra-violet. The result was as follows :—

Number of Daphnias.

	Ultra-violet.	Violet.	Blue.	Dark.
Exp. 1.	1	9	38	2
„ 2.	4	6	38	2
„ 3.	0	2	46	2

I afterwards gave them only the option of ultra-violet, violet, and darkness:—

	Ultra-violet.	Violet.	Dark.
Exp. 1.	8	48	4
„ 2.	6	48	6
„ 3.	12	47	1
„ 4.	15	42	3
„ 5.	4	53	3
	45	238	17

I then tried ultra-violet and dark. The width of the violet was 2 inches; and I divided the ultra-violet portion again into divisions each of 2 inches, which we may call ultra-violet, further ultra-violet, and still further ultra-violet. The results were:—

Number of Daphnias.

	Still further ultra-violet.	Further ultra-violet.	Ultra-violet.	Dark.
Exp. 1.	0	6	52	2
„ 2.	0	5	52	3
„ 3.	0	6	50	4
„ 4.	0	4	53	3
„ 5.	0	4	54	2
		286		14

May 18.—I again tried them with the ultra-violet rays, using three divisions—namely further ultra-violet, ultra-violet, and dark. The numbers were as follows, viz. under the

	Further ultra-violet.	Ultra-violet.	Dark.
Exp. 1.	6	50	4
„ 2.	3	55	2

To my eye there was no perceptible difference between the further ultra-violet and the ultra-violet portion; but slightly undiffused light reached the two extreme divisions. It may be asked why the still further ultra-violet division should have been entirely deserted, while in each case two or three Daphnias were in the darkened one. This, I doubt not, was due to the fact that the darkened division being next to the ultra-violet, one or two in each case straggled into it.

Not satisfied with this, I tried to test it in another way.

I placed over the ultra-violet division a glass cell containing a layer of sulphate of quinine about $\frac{3}{8}$ inch in depth, and over the further ultra-violet a similar cell with water. I had expected that the great majority would collect under the water-cell. The numbers, however, were :—

	Further ultra-violet, with cell containing water.	Ultra-violet, with cell containing sulphate of quinine.
Exp. 1.	8	50
„ 2.	4	54
„ 3.	11	49
„ 4.	4	56

The reason of this, however, seemed evident as soon as I tried the experiment, because, though the sulphate of quinine stops the ultra-violet rays, it turns them into blue light, and, to our eyes at least, actually increases the brilliance.

I then took a cell in which I placed a layer of 5-per-cent. solution of chromate of potash less than an eighth of an inch in depth, which, though almost colorless to our eyes, completely cut off the ultra-violet rays. I then turned my trough at right angles, so that I could cover one side of the ultra-violet portion of the spectrum with the chromate and leave the other exposed. The numbers were as follows :—

	Side of the ultra-violet covered with chromate of potash.	Side uncovered.	Dark.
Exp. 1.	5	55	0
	I now covered up the other side.		
„ 2.	3	57	0
	Again covered up the same side as at first.		
„ 3.	4	56	0
	Again covered up the other side.		
„ 4.	3	57	0

May 19.—Again the same arrangement. I reduced the chromate of potash to a mere film, which, however, still cut off the ultra-violet rays. I then placed it, as before, over one half of the ultra-violet portion of the spectrum; and over the other half I placed a similar cell containing water. Between each experiment I reversed the position of the two cells. The numbers were :—

	Under the film of chromate of potash.	Under the water.
Exp. 1.	8	52
„ 2.	4	56
„ 3.	10	50
„ 4.	7	53

Evidently even a film of chromate of potash exercises a very considerable influence; and indeed I doubt not that, if a longer time had been allowed, the difference would have been even greater.

It seems clear, therefore, that a film of a 5-per-cent. solution of chromate of potash only $\frac{1}{8}$ inch in thickness, which cuts off the ultra-violet rays, though absolutely transparent to our eyes, is by no means so to the Daphnias.

I then again returned to the sulphate of quinine; but instead of placing it close to the water, I suspended it at a height of 3 feet, so that the Daphnias were far less directly illuminated by the scattered light.

As in the preceding case, I placed by the side of it a similar cell containing water, and suspended them side by side over the water containing the Daphnias, and reversed the position after each experiment. The numbers were as follows:—

	Under the sulphate of quinine.	Under the water.
Exp. 1.	13	47
„ 2.	17	43
„ 3.	12	48
„ 4.	11	49
„ 5.	20	40
„ 6.	18	42
„ 7.	20	40
„ 8.	15	45

Although the contrast in this latter series is not so great, still it is unmistakable. It seems to me, therefore, though I differ with great reluctance from so eminent an authority as M. Paul Bert, that the limits of vision of Daphnias do not, at the violet end of the spectrum, coincide with ours, but that the Daphnia, like the ant, is affected by the ultra-violet rays.