TESTIS ACTIVITY IN *STURNUS VULGARIS* RELATION TO ARTIFICIAL SUNLIGHT AND TO ELECTRIC LIGHTS OF EQUAL HEAT AND LUMINOUS INTENSITIES.[1]

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INTRODUCTION

IN previous studies of the effects of electric lights used to prolong the daily periods of light for *Sturnus vulgaris*, and, particularly, of that from the "sunlamp" of the General Electric Company in relation to light of restricted wave-length and from other sources, it was noticed that the luminous intensity of the "sunlamp" closely approximated that of a 200-watt incandescent bulb. On the other hand, its "heat" intensity, as measured by a thermopile and galvanometer with variable resistance, at the distances used, was of the order of that from a 1000-watt bulb similarly used. (Bissonnette, 1930a, b, 1931a, b, 1932a, b, c, d, e; Bissonnette and Chapnick, 1930; Bissonnette and Wadlund, 1931, 1932).

These previous studies indicated that the effects on testis activity in Starlings (*Sturnus vulgaris*) of filtered red, filtered green, and unfiltered white light from incandescent bulbs were not proportional to the total heat energy reaching the roost on which the birds perched, and around which they circulated in the cages. With equal luminous intensities of lights so used, the heat equivalents were, red, 10; green, 2.5; white, 1; and controls, 0; while the relative amounts of stimulation of testis activity were in the descending order, red, white, control, green.

These findings suggested that it would be well to determine the relative effects, in this connection, of ordinary incandescent lights of equal luminous intensity and of equal "heat" intensity, as compared with the "sunlamp", with its content of ultra-violet and its somewhat different spectrum (Bissonnette and Wadlund, 1932). As birds of similar known previous light

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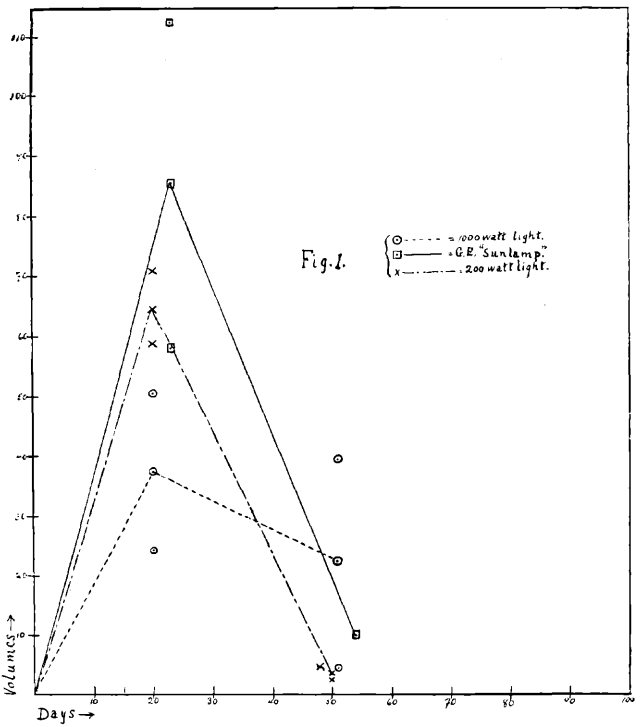


Figure 1. Graphs of changes in testis volumes of "1000 watt," "sunlamp," and "200 watt" birds.

history were available, the effects on three different cages of birds were tested, with the "sunlamp" acting on one cage, an incandescent bulb at equal luminous intensity on a second cage, and another incandescent bulb at equal "heat" intensity acting on a third cage.

The results proved very interesting and were consistent with those from previous experiments and with the conclusions drawn from them.

MATERIAL AND METHOD

Between March 25 and June 11, 1931, three cages of birds previously kept as controls, on a restricted "light ration"[2] of

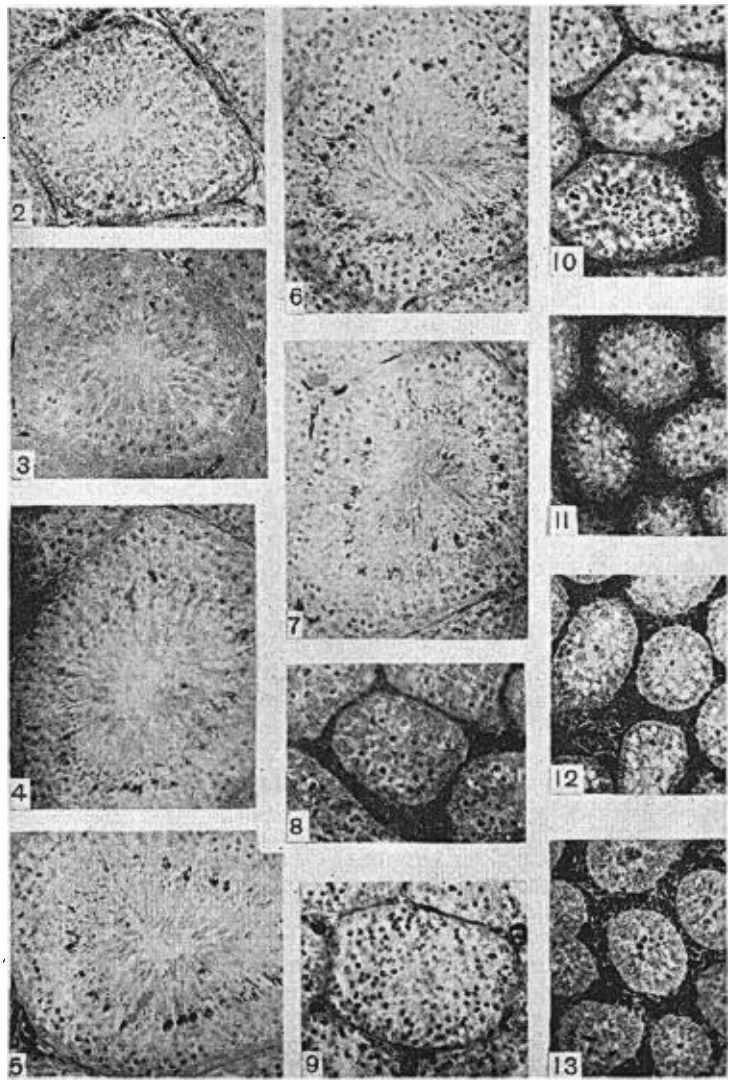
[2]Throughout this paper "light ration" is used to denote time × intensity of daily illumination and type of rays used for artificial lighting, *i.e.*, "sunlamp" or ordinary light from incandescent bulbs.

nine and one half hours of daylight per day in a basement room (Bissonnette and Wadlund, 1932), were taken for experiments. Conditions of their testes at the beginning of the experiment are shown in the preceding paper of this series (Bissonnette and Wadlund, 1932, fig. 18, Table I), with their average total testis volume per bird (about 5 cu. mm). No inside controls were kept for comparison with these three sets of birds, because the available birds, with controlled previous light history, were few in number and the reduced "light ration" was known to keep birds indefinitely in winter testis condition (Bissonnette, 1931a, and subsequent studies).

Light from a General Electric Company's "sunlamp", with reflector, was thrown laterally into one cage, hereinafter called the "sunlamp" cage, from a distance of 24 inches from the center of the roost, giving 80 lumens per square foot at the roost. Into another cage, the "200-watt" cage, light from a 200-watt clear lamp, with reflector, was thrown in the same way from 36 inches distance, also giving 80 lumens per square foot at the roost. The candle-power of the "sunlamp" was determined as previously described (Bissonnette and Wadlund, 1932), and that of the 200-watt bulb was determined by comparison with the "sunlamp", on the same apparatus. The total "heat" intensity at the roost from the "sunlamp" was then determined by a thermopile-galvanometer apparatus, with variable resistance, as described. Then into a third cage, the "1000-watt" cage, light from a 1000-watt incandescent bulb, with reflector, was thrown in the same way, from such a distance that the deflection of the galvanometer, with the same arrangement of apparatus as for the "sunlamp", was the same. The lights were fixed at these distances throughout the experiment.

Diets were similar to those used in previous experiments and were rich in proteins, fats, and vitamins, to prevent interference, of deficiency in these respects, with the sexual activities of the birds.

The "sunlamp" was turned on for three evenings from March 25th–28th before the other lamps were used, owing to a misunderstanding between the authors. Ten days were allowed to elapse after these three days before the experiment began in earnest, to let the effects of these three days moderate. For this reason "sunlamp" birds were illuminated for three days longer than were the others, when killed on the same dates. This is recorded in Table I. Owing to the small numbers of birds available, it was not possible to discard these birds owing to their "false start". Just what were the effects of the elapsed



Figures 2–13. Photomicrographs of sections from testes taken at 335. diameters in all cases and reduced to about 170 diameters, in reproduction.

ten days, in modifying the results of the experiment, cannot be judged with certainty as yet.

Comparison of graphs of testis-volume changes with germ-cell changes leads to the conclusion that histological changes and conditions are more characteristically and reliably correlated with "light ration" changes than are testis-volume changes (Table I, Plate figures 1–13, and text figure 1). Table I gives condensed data on the testes of birds killed for study after 20, 23, 48, 51, and 54 days of light treatments.

All three lights were turned on the six hours per night by an electric time switch after a nine-and-a-half hour daily daylight period, as in previous studies. Deaths during the experiment were three in number, and all birds were anæmic toward the end and had the small feathers drop out round the base of the bill, the eyes, and the throat. This was not due to wearing off against the cage, but was probably due to reaction to privation of some sort, such as lack of some types of wave-length of light while being kept as controls behind glass from January 20th till May and June. Their intestines were light-colored and their bills long and pale in color. "Sunlamp" birds were like the others in these respects, indicating that light from such a source did not induce recovery in the time during which it was acting upon them. Juvenile characteristics of bill and plumage disappeared in all birds before they were killed, except in one female.

GENERAL RESULTS

The 200-watt incandescent lamp proved most rapidly effective; the "sunlamp" slightly less so; and the 1000-watt lamp, least so. In 20 days, the 200-watt lamp caused the testes to reach and pass their climax of activity, and, probably, of size (Plate I, figs. 6, 7; text—fig. 1). In 23 days of action (3 days before a break of 10 days without added light, and 20 days of light treatments following it), the "sunlamp" caused testes to reach almost their climax (figs. 4, 5, Plate I). In 20 days, the 1000-watt lamp induced much less advanced stages in the testes of the birds exposed to its light. No stages beyond a few metamorphosing spermatids and very early sperms were induced by this lamp with its much more intense luminosity than those of the other two lamps (plate- figs. 2, 3).

In 51 days, the testes of "1000-watt" birds passed over into regression (plate-figs. 8, 9); but did not proceed so far as did those of "sunlamp" birds in 54 days (plate-fig. 10). Their regression was apparently less rapid or began later than that of the "sunlamp" birds. Disorganization was less pronounced. Testes of "200-watt" birds, in 48 days (plate-fig. 11) and in 50

TABLE 1.—DATA RELATING TO BIRDS KILLED AT VARIOUS PERIODS OF LIGHT TREATMENT

Days in Light	*Type of Light*	*Testis size right and left, in millimeters*	*Total testis volume in cu. millimeters*	*Serial No.*	*Figures in Plates*	*Histological and other testis data per bird*
20	1000-watt	R.— 8.4 × 5.5 L.— 8.9 × 5.0	227.4	D. 2	Fig. 3	All germ-cell stages up to spermatids; no metamorphosing sperms yet; interstitial cells not recognizable; pigment scattered.
20	1000-watt	R.— 9.5 × 7.6 L.— 9.8 × 6.8	524.8	D. 1	Fig. 2	Metamorphosing sperms just appearing; tubules about 5/7 maximum diameter; otherwise as above.
23	"Sunlamp"	R.—10.8 × 7.4 L.—12.1 × 6.6	586.3	D. 3	Fig. 4	Tubules approaching maximum diameter; sperms almost complete; interstitials not recognizable; pigment scattered.
23	"Sunlamp"	R.—12.2 × 9.1 L.—13.9 × 9.1	1132.0	D. 4	Fig. 5	Tubules almost maximum diameter; sperms mature; germ-cells of all stages very numerous.
20	200-watt	R.—10.6 × 8.0 L.—12.5 × 7.3	703.8	D. 5	Fig. 6	Past climax of activity; sperms mature and numerous; spermatids and secondary spermatocytes disappearing or failing to form; tubules shrinking; sperms free.
20	200-watt	R.—10.5 × 7.4 L.—11.9 × 6.8	589.4	D. 6	Fig. 7	Similar to the above but farther in regression; interstitials not yet recognizable as such; still like connective tissue.
51	1000-watt	R.— 4.6 × 3.1 L.— 5.2 × 3.0	47.7	D. 8	Fig. 8	Far gone in regression; approaching June 8/15th stage in nature; necrosis and phagocytosis of germ-cells; few synizesis stages of growing spermatocytes and spermatogonia present; interstitials rounding up.
51	1000-watt	R.— 8.4 × 7.3 L.—10.0 × 5.6	399.0	D. 9	Fig. 9	Not so far regressed as the above; necrotic nuclei and debris still present; synizesis stages more numerous; no sperms; interstitials not yet recognizable.
54	"Sunlamp"	R.— 5.8 × 4.3 L.— 6.7 × 3.5	100.0	D. 10	Fig. 10	More regressed than the two just above; necrotic cells still present; synizesis stages rarer; fewer normal germ-cells present; farther along than the above two.
48	200-watt	R.— 4.0 × 3.0 L.— 4.1 × 2.9	36.9	D. 11	Fig. 11	Even farther regressed than the preceding; vacuolated Sertoli cell outlines very plain; germ-cells all gone but spermatogonia; interstitials rounded and recognizable.
50	200-watt	R.— 4.0 × 2.6 L.— 4.3 × 2.3	26.2	D. 12	Fig. 12	Two days later; regression still farther along; otherwise like the above; stage of June 15th to August 1st.
50	200-watt	R.— 4.3 × 2.9 L.— 4.5 × 2.3	31.4	D. 13	Fig. 13	Like the preceding; but vacuoles smaller; farther advanced; testis tubules reorganizing into autumn condition; August and September stages of natural cycle.

days (plate-figs. 12, 13), were far in advance of the other two sets of birds' testes, so far as regression is concerned. This was shown by smaller testis size, smaller tubule diameter, and much reduced intratubular tissue (text-fig. 1).

All the birds subjected to any of the three types of experimental "light ration" reached the climax of spermatogenic activity and passed over into regression in different degrees. The optimum light intensity and optimum type of spectrum, so far as colors and wave-lengths of light are concerned, appeared to lie nearer to those of the 200-watt lamp than to those of either of the other two lamps. Light from the 1000-watt lamp was either too intense in luminosity or of less effective proportions of the different wave-lengths than that of the 200-watt lamp. That of the "sunlamp", though of the same luminous intensity, was evidently either weaker in the more effective long wave-lengths (red rays) or stronger in the types of wave-length which are inhibitory to sexual and spermatogenic activity indicated by our previous studies (Bissonnette, 1930a, b, 1931a, b, 1932a, b; Bissonnette and Chapnick, 1930; Bissonnette and Wadlund, 1931, 1932).

DISCUSSION

The results outlined above are taken to indicate that, (1), ordinary electric light from incandescent lamps of the luminous intensity of 80 lumens per square foot at the roost is more effective as a testis-activator than the same luminous intensity of artificial midsummer sunlight as emitted by the "sunlamp", with its less restricted spectrum and different proportions of the various wave-lengths (Bissonnette and Wadlund, 1932); (2), light from a 1000-watt incandescent lamp is either of too great luminous intensity, if used at the proper distance to give the "heat" equivalent of the "sunlamp", or has a proportion and distribution of its wave-lengths less stimulating as a whole than those of the 200-watt lamp used; it is probably above the optimum in luminous intensity.

This raises the question as to just what constitute the optimum luminous intensity and proportions of the various wave-lengths of incandescent light, used as activators of testis activity. This is being studied from various angles. Our recent studies suggest the probability that monochromatic light of a rather restricted region of the spectrum, in the long-waved end (red), is almost if not entirely responsible for the activation of the sex-glands in Starlings (Bissonnette, 1932b; Bissonnette and Wadlund, 1931, 1932).

These studies showed that red light, with its long waves, was

potent in this respect, while green light, with its shorter waves, but of equal luminous intensity and acting for the same daily periods, was not only ineffective but inhibitory. Violet light, in the much less intensity so far available for use, did not prove stimulating but was probably inhibitory. Hill and Parkes (1931), working with ferrets during the long winter anœstrum, found that ultra-violet, of the range of wave-lengths used, did not stimulate these animals to œstrous activity, when used for five minutes daily for ten days in November, and were led to the conclusion that light was, at most, a very minor factor in sexual periodicity. Bissonnette, however, working on the same animal, found that visible light, from 200-watt incandescent lamps, did induce œstrum in female ferrets in about six weeks in the period from October to February, leading to copulations in December and February, with light-stimulated males from the same room. The males, however, did not produce sperms, though both the germ-cells and the interstitial cells were stimulated somewhat, leading to increased libido and copulations and to the breeding condition of the epididymis. These midwinter copulations led to pseudo-pregnancies in all cases, with all the changes in the female sexual and mammary systems normal to such pseudo-pregnancy, as described by Marshall (1904) and Hammond and Marshall (1930); (Bissonnette, 1932c). These studies suggest that differences in the proportions of the different wave-lengths of visible electric light give differences in amounts of stimulation of sexual activity, leading to sexual periodicity in some birds and mammals, though probably not in all, or not to the same extent in all.

This study lends support to our conclusions from previous studies that "heat" intensity of the incident light is not as great a factor in conditioning sexual periodicity in these birds as are either luminous intensity or wave-length. An optimum wave-length and an optimum intensity are indicated.

A somewhat similar situation with regard to some of the vitamins has been suggested. An optimum wave-length in the ultra-violet for the activation of ergosterol to give vitamin D has been indicated, with all other wave-lengths, not only not effective, but actually causing reversal of the process, or a change in physical characteristics of the solution containing the vitamin D or the pro-vitamin in the ergosterol; though the matter seems to be still in the controversial stages of the investigations (Bowden and Snow, 1932a, b; Heilbron and Morton, 1932; Morton and Heilbron, 1928, and others).

Some such very limited band of wave-lengths in the visible part of the spectrum may, possibly, be the only effective light region for activation of sex-gland activity. Other cases of

differences in reaction to different wave-lengths of light have been discussed in previous papers and will not be gone over again (Bissonnette, 1931b, 1932b; Bissonnette and Wadlund, 1931, 1932). It is enough to state that phenomena of specificity of definitely limited regions of the spectrum, if not of strictly monochromatic light, are, apparently, widespread in Nature and this is merely one of its many manifestations.

That the anterior lobe of the hypophysis (and possibly the adrenals) probably mediates this light-induced sexual periodicity has been suggested elsewhere (Bissonnette, 1932c, d.).

That even human beings are susceptible to modification of sexual cycles and activity, by changes in periods of exposure to light, and possibly to changes in intensity and wave-length, as well as some birds, and ferrets and voles (Baker and Ranson, 1932) among mammals, is indicated by the loss of sexual activity, libido, and menstruation by Eskimo men and women during the long arctic night and by a similar reaction on the part of the members of the Peary polar exploration party of 1894, cited by Llewellyn (1932).

SUMMARY

(1) A study was made of the relative effects on testis activity in Starlings of lights from (a) a "sunlamp" with visible and some ultra-violet radiations, (b) an incandescent lamp giving equal luminous intensity, (c) an incandescent lamp of greater luminous intensity giving equal total "heat" intensity.

(2) Birds were exposed to these three lamps for equal periods after dark and killed at stated times for study of their effects.

(3) Of the lights used, the descending order of effectiveness as testis-activators was (b), (a), (c); and, as in previous studies, testes of birds, under all three types of light exposure, passed the climax of activity and underwent regression long before 48 days of treatment.

(4) The results are taken to indicate an optimum luminous intensity of light, nearer that from the (b) lamp than that from the (c) one which is evidently above the optimum; that the combination of wave-lengths emitted by the (b) lamp used is more effective than that of the "sunlamp" (a), possibly on account of its probable greater content of long-waved red rays or its smaller content of inhibitory wave-lengths.

(5) The possibility of the specificity of a very restricted region of the visible spectrum, somewhere in the red, for sexual activating powers, and the ineffectiveness of wave-lengths from other regions are discussed.

(6) Instances of such cases of sexual photoperiodicity among

mammals and even in man are cited and their bearings on the general problem of sexual photoperiodicity are discussed.

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LEGENDS

FIG. 1. Graphs of testis-volume changes in birds subjected to illumination after dark by 1000-watt and 200-watt incandescent bulbs at distances required to give the heat equivalent and the luminous equivalent respectively of a "sunlamp" at 24 inches distance, as compared with volume changes in birds lighted by the "sunlamp" at that distance. In the graphs one unit of volume is equal to twice the testis volume of similar birds at the beginning of the experiments.

PLATE I.

N. B.—Figures in the plate are photomicrographs of testis sections taken at 335 diameters in all cases and reduced to about 223 diameters.

FIG. 2. Tubules from bird subjected to light from 1000-watt bulb for 20 days. D1.

FIG. 3. Tubules from a bird subjected to light from a 1000-watt bulb for 20 days. D2.

FIG. 4. Tubules from a bird subjected to light from a "sunlamp" for 23 days. D3. Total "heat" of this lamp reaching the birds was equal to that reaching the birds furnishing sections for figures 2, 3.

FIG. 5. Tubules from a bird subjected to light from a "sunlamp" for 23 days. D4.

FIG. 6. Tubules from a bird subjected to light from a 200-watt bulb for 20 days. D5. Light intensity reaching this and the bird for figure 7 was equal to that from the "sunlamp" reaching birds furnishing sections for figures 4, 5.

FIG. 7. Tubules from a bird subjected to light from a 200-watt bulb for 20 days. D6.

FIG. 8. Tubules from bird subjected to light from a 1000-watt bulb for 51 days. D8.

FIG. 9. Tubules from a bird subjected to light from a 1000-watt bulb for 51 days. D9.

FIG. 10. Tubules from a bird subjected to light from a "sunlamp" for 54 days. D10.

FIG. 11. Tubules from a bird subjected to light from a 200-watt bulb for 48 days. D11.

FIG. 12. Tubules from a bird subjected to light from a 200-watt bulb for 50 days. D12.

FIG. 13. Tubules from a bird subjected to light from a 200-watt bulb for 50 days. D13.