Table 2. Interatomic distances in the $CdGeO_3$ structure. Standard errors for all distances are ± 0.01 Å.

Atom	Neighboring atom	Distance (Å)
Cd(1)	O(1)	2.25
	O(2)	2.65
	O(3)	2.44
	O(3)	2.44
	O(4)	2.49
	O(4)	2.30
	O(5)	2.30
	O(6)	2.76
	O(av.)	2.45
Cd(2)	2O(1)	2.36
	2O(2)	2.56
	2O(5)	2.32
	2O(6)	2.40
	O(av.)	2.41
Cd(3)	2O(1)	2.29
	2O(4)	2.21
	2O(5)	2.22
	O(av.)	2.24
Ge(1)	2O(2)	1.90
	2O(3)	1.89
	2O(6)	1.90
	O(av.)	1.90
Ge(2)	4O(5)	1.78
Ge(3)	4O(6)	1.78
Ge(4)	O(1)	1.77
	O(2)	1.79
	O(3)	1.82
	O(4)	1.79
	O(av.)	1.79

gives the equipoints (equivalent positions), based on this new orientation, of *Ia3d* occupied in the garnet structure and the related equipoints of $I4_1/a$ occupied in the $CdGeO_3$ structure. In $CdGeO_3$, Cd(1) and Cd(2) occupy dodecahedral sites, Cd(3) and Ge(1) octahedral sites, and Ge(2), Ge(3), and Ge(4) tetrahedral sites; there are six oxygen sites. The oxygen sites in $CdGeO_3$ are related to the oxygen site in garnet by the following transformations: x,y,z; $x,\bar{y},\frac{3}{2}-z$; $\frac{1}{4}-x,\frac{3}{4}-z,\frac{3}{4}+y$; $\frac{1}{4}-x,-\frac{3}{4}+z,\frac{3}{4}-y$; $\bar{y},-\frac{1}{2}+z,\frac{1}{2}-x$; $-\frac{3}{4}+z,\frac{1}{4}-y,\frac{3}{4}+x$.

Full-matrix least-squares refinement reduced R ($R = \Sigma|\,|F_{obs}|-|F_{calc}|\,|\div\Sigma|F_{obs}|$, where F is the structure factor) to 0.073 for all the observed reflections. The weighted R was 0.080. In the final cycle of refinement, the scale factor, secondary extinction parameter (C), appropriate atom coordinates, and isotropic temperature factors (B) were varied. The final isotropic temperature factors (Table 1) are all reasonable, although the calculated errors for the B values for oxygen are rather large. This may reflect a somewhat poorer agreement for weak reflections where $l \neq 2n$.

The symmetry of the $CdGeO_3$ structure is lower than that of garnet because all the cadmium and germanium atoms are ordered into distinct crystallographic sites. Examination of the garnet structure shows that this is not the only possible ordering. For example, atoms in the octahedral sites (16*a*) in the space group *Ia3d* could order so as to occupy equipoints 8*a* and 8*b* *Ia*3. The dodecahedral and tetrahedral sites would be 24*d* in *Ia*3, and there would be two oxygen atoms in 48*e*. This would require that additional reflections be present because of the loss of the *d* glide plane. To our knowledge, no such ordering has been observed, but possibly this or some other scheme might be as probable as the one observed for $CdGeO_3$.

Reports of noncubic garnets are not restricted to $CdGeO_3$ and $CaGeO_3$ (*3*). Apparently garnets such as uvarovite ($Ca_3Cr_2Si_3O_{12}$), grossularite ($Ca_3Al_2Si_3O_{12}$), and andradite ($Ca_3Fe_2Si_3O_{12}$) are often optically anisotropic, whereas those such as pyrope ($Mg_3Al_2Si_3O_{12}$), almandite ($Fe_3Al_2Si_3O_{12}$), and spessartite ($Mn_3Al_2Si_3O_{12}$) are not. Furthermore, although the external form of anisotropic garnets is usually cubic, the crystals are actually twinned composites of either uniaxial or biaxial individuals. Birefringence disappears at about 800°C and may or may not reappear upon cooling. Although anisotropic character seems to be associated with a large cation in the dodecahedral site, structure refinements of pyrope also raise questions about small cations in the dodecahedral site. Zemann and Zemann (*7*) suggested that magnesium is not actually in the center of the dodecahedron but rather is statistically distributed on either side of the center. Gibbs and Smith (*8*), however, thought that this was due to thermal anisotropy and was not a static displacement.

Table 2 lists the interatomic distances for the $CdGeO_3$ structure. Cd(1) and Cd(2) are each surrounded by eight oxygen atoms in a distorted triangular dodecahedron at average distances of 2.45 Å and 2.41 Å, respectively; the distance between ^{VIII}Cd and ^{IV}O, predicted on the basis of the Shannon and Prewitt (*9*) table of effective ionic radii, is 2.45 Å. Some difficulty exists with Cd(3), however, because it is octahedrally coordinated with an average distance of 2.24 Å, whereas the predicted value for the distance between ^{VI}Cd and ^{IV}O is 2.33 Å. It is difficult to explain this large difference because it seems unlikely that there could be a mixing of Ge and Cd in the octahedral sites. The average observed distance between Ge(1) and oxygen is 1.90 Å; the predicted value is 1.92 Å, thus effectively eliminating the possibility that Cd might be substituting for Ge here. The anomaly might be a real feature since unusual interatomic distances are often found in garnet structures. The tetrahedral Ge-O distances of 1.77 Å, 1.78 Å, and 1.79 Å are in good agreement with the predicted value of 1.78 Å (Table 2).

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Bird Energetics: Effects of Artificial Radiation

Abstract. *Radiant energy reduces oxygen consumption in birds; this reduction is correlated with feather color, being greater in dark birds (26 percent reduction) than in white ones (6 percent reduction). With radiant energy (basking), the cowbird effectively increased its insulation, thus shifting the lower end of the zone of thermal neutrality down by as much as 10°C (35° to 25°C).*

Some birds sunbathe (*1*) and Lanyon (*2*) has suggested that the stimulus which initiates sunbathing behavior is heat. As early as 1925, Cartwright and Harrold (*3*) set forth the hypothesis that a governing principle of avian metabolism is radiant energy and that the absorption of this radiation is dependent upon the coloration of the plumage. Morton (*4*) showed that at low air temperatures, white-crowned sparrows (*Zonotrichia leucophrys*) that received radiant energy

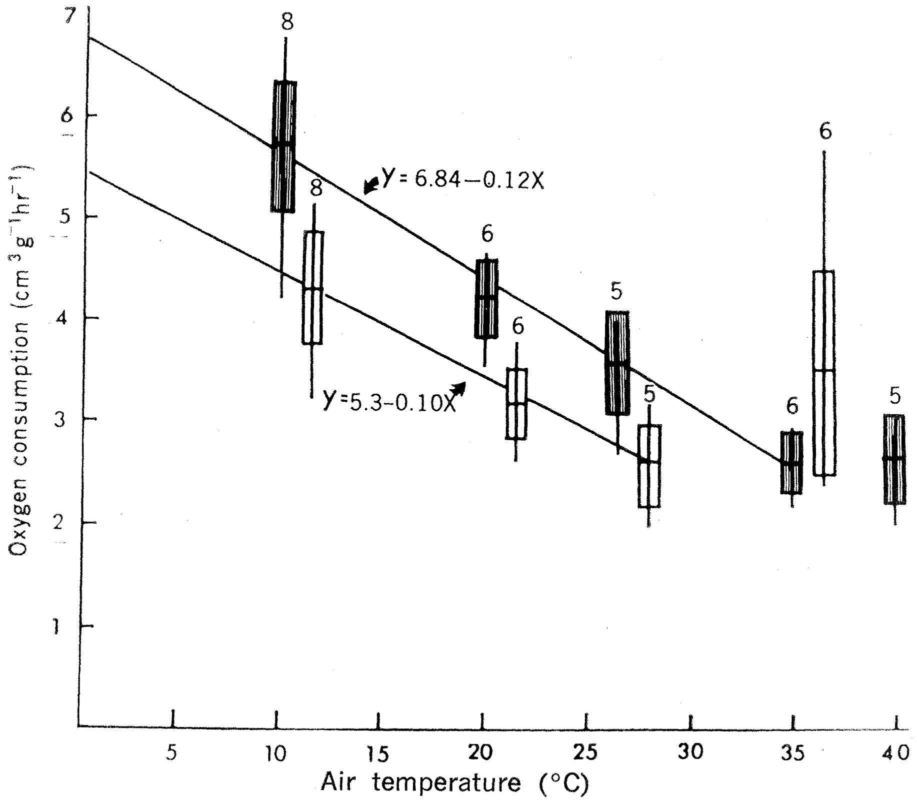

Fig. 1. The oxygen consumption of cowbirds receiving artificial radiation (unshaded boxes) and cowbirds not receiving artificial radiation (shaded boxes). Vertical lines represent the range, horizontal lines the mean, and the boxes the 95 percent confidence limits ("t" times standard error of mean). The numerals show the number of birds measured at each temperature. The unshaded boxes are shifted slightly to the right to avoid confusion.

consumed less food than those that were not exposed. However, he did not ascertain whether the decrease in food intake during exposure to radiant energy actually resulted in a reduction in total daily energy expenditure. Recently Hamilton and Hepner (5) reported that albino zebra finches (*Poephila castanotis*), when dyed black and exposed to artificial radiation, showed a reduction in the metabolic expenditure necessary for thermoregulation at low air temperature (10°C), and the reduction was more than in undyed controls. From this they inferred that the dyed birds absorbed more radiant energy than the undyed birds. Their experiments left some doubt about whether the decrease in metabolism (caused by the absorbed radiant energy) of the dyed birds exposed to radiation was due to black coloration, to some change in feather structure, or to the fact that the dye itself absorbed more radiant energy. With this in mind, I repeated the experiments of Hamilton and Hepner; I used cowbirds (*Molothrus ater obscurus*) (males, normally black; females, normally brown), albino zebra finches, and wild type dark-gray zebra finches. Two questions were considered; can a bird take advantage of solar radiation in thermoregulation, and what effect does coloration have on the use of solar radiation?

The experimental setup was similar to that of Hamilton and Hepner and consisted of a plexiglass metabolic chamber (22 by 22 by 32 cm) fitted with three thermocouples, an air intake, and an air outlet. Centered in the top surface of the respiration chamber was an opening (13 by 13 cm) over which a glass plate (3 mm thick) was sealed with Keystone heavy-duty grease. During the experiment, the chamber containing the bird was submerged in an Aminco temperature-controlled bath of circulating water (185 liters capacity) so that the glass window was covered by 1 cm of water. The radiation source, a General Electric infrared lamp (R-40, 250-watt clear-end) (color temperature 2500°K) was centered directly over the window 40 cm above the floor of the submerged respiration chamber. The bird in the respiration chamber received light of wavelengths from 400 to 1400 nm, the upper limit of infrared radiation passing through 1 cm of water (*6*). A Belfort pyroheliometer recorded approximately 0.9 cal cm^{-2} min^{-1} at 7 cm above the floor of the submerged respiration chamber. Air temperature was recorded with a Honeywell potentiometer from three thermocouples, two placed 4 cm above the floor of the respiration chamber and one in the air outlet. All thermocouples were shielded from direct radiation. The air temperature was maintained within ± 0.5°C of that desired. Cowbirds were tested at air temperatures of 10°, 20°, 26.5°, 35°, and 40°C, whereas zebra finches were tested only at 10°C. The birds remained quiet during the tests, usually sitting in the center of the chamber.

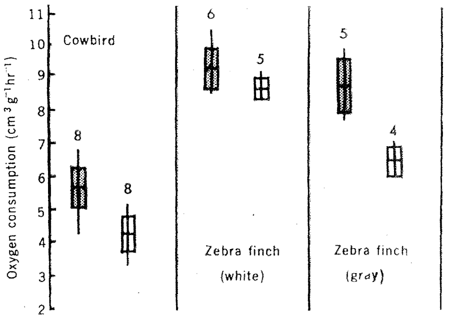

Fig. 2. Oxygen consumption in the cowbird, albino zebra finch, and wild type zebra finch with (unshaded) and without (shaded) artificial radiation (symbols as in Fig. 1), recorded at an air temperature of 10°C.

Oxygen consumption was monitored with a Beckman G-2 paramagnetic oxygen analyzer in an open-circuit system. The air flow through the chamber was 1000 cm^3 min^{-1} and all calculations were based on the starting weight of the birds. Experiments were performed in the following sequence on birds that had been fasted for at least 4 hours and were maintained on a 12-hour photoperiod (9 a.m. to 9 p.m.). (i) The bird was placed in the chamber and allowed to attain a steady state of oxygen consumption before any readings were taken. The bird received illumination from the fluorescent room lights throughout the test. (ii) Next the infrared R-40 lamp was turned on, and the oxygen consumption was allowed to become stabile at the new level before any readings were taken. (iii) The R-40 lamp was turned off, and step one was repeated.

Reflectance of the plumage was measured with a Beckman DK-2A recording-reflecting spectrophotometer (7) with wavelengths from 400 to 2100 nm. Reflectances were determined from measurement of the dorsal surfaces of the birds used in the oxygen consumption experiments and from study skins in the University of California, Los

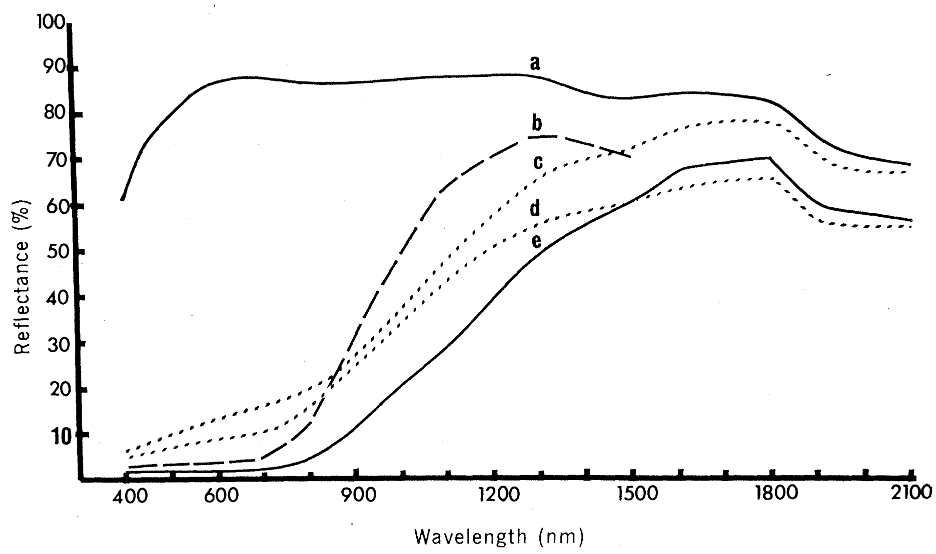

Fig. 3. Reflectance from the dorsal surfaces of the birds tested as a function of wavelength; (*a*) albino zebra finch; (*b*) albino zebra finch dyed black; (*c*) wild type zebra finch; (*d*) female cowbird; (*e*) male cowbird.

Angeles collection. Also, an albino zebra finch was dyed black with Nayanzol-Dye and tested for reflectance.

Exposure of cowbirds to radiant energy decreased their oxygen consumption by about 26 percent at air temperatures between 10° and 26.5°C and reduced the lower limit of the thermal neutral zone by about 10°C (Fig. 1). The upper end of the zone of thermal neutrality was also lowered. At temperatures below 35°C, many of the birds assumed a sunbathing posture.

The oxygen consumptions of albino zebra finches, wild type zebra finches, and cowbirds are compared at an air temperature of 10°C with and without added radiation in Fig. 2. There was no significant difference in oxygen consumption in radiated and control albino zebra finches. However, both cowbirds and wild type zebra finches showed a decrease in oxygen consumption of about 26 percent when they received radiation. There was no difference in oxygen consumption between the male (black) and female (brown) cowbirds either with or without radiation treatment.

Since no radiation is transmitted through a feather layer (*7*), all incident radiation must be either absorbed or reflected. When reflection is low, absorption must be high and absorbed radiation is transformed to heat.

The data on reflectance (Fig. 3) substantiate the results obtained from oxygen consumption measurements. The albino zebra finches that showed the least reduction in oxygen consumption when exposed to radiant energy had the lowest absorbance over the wavelengths tested. The other birds had absorbance curves differing only by about 15 percent. An albino zebra finch that was dyed black had an absorbance in the visible range (400 to 760 nm), the same as the absorbance of the black male cowbird; in the near infrared (760 to 1500 nm) the absorbance was similar to that of the wild type zebra finches. The biggest differences in absorbance by the white birds tested lies in the visible and near infrared (Fig. 3).

Approximately 40 percent of the direct solar energy lies in the visible light (390 to 760 nm) and approximately 50 percent in the near infrared (760 to 2000 nm) (*8*). At longer wavelengths (above 1500 nm), the ratio of absorbance to reflectance is independent of color (Fig. 3). Absorbance and the percentage of decrease in oxygen consumption in brown female cowbirds, black male cowbirds, and dark-gray zebra finches receiving insolation differed very little. It would seem that most birds (other than white) can take advantage of solar radiation in thermoregulation.

The downward shift in both the upper and lower end of the zone of thermal neutrality of birds receiving artificial insolation can be interpreted as an effective increase in the insulation (*9*). Since a feather layer generally transmits no radiation, one can assume that the downward shift in the zone of thermal neutrality in birds receiving artificial insolation is not due directly to the absorption of solar radiation. Thus with an increase in the surface temperature of the feathers due to absorbed radiation, there could reasonably be a decrease in the thermal gradient from the skin surface to the feather surface which reduces conductive heat loss.

Morton (*4*) found that irradiated birds consumed the same amount of food as nonirradiated birds at an ambient temperature slightly below the known lower critical temperature. He interpreted this to mean that radiation was not needed for thermoregulation at a temperature slightly below the lower critical temperature, since there was an added heat increment from exercise and specific dynamic action. Though it is true that the birds studied by Morton had an extra heat load due to exercise and specific dynamic action the thermal neutral zone probably had been lowered by increasing the effective insulation with radiation. In my experiments, the birds were fasted and quiet while tested, so the fact that oxygen consumption in irradiated birds at 26.5°C was the same as that in nonirradiated birds at 35° and 40°C is consistent with the hypothesis that radiation reduces oxygen consumption by causing an effective increase in insulation.

The fact that the lower end of the thermal neutral zone of cowbirds is shifted down approximately 10°C by radiant energy suggests that birds could achieve a considerable savings (26 percent) in metabolic energy at low air temperatures by exposing themselves to solar radiation. Possibly this downward shift in thermal neutrality would be even greater under natural conditions than under my experimental conditions. In active cowbirds, there would be an increased increment due to exercise and specific dynamic action and an increased insulation due to radiation. Though it is known that long-term acclimation can shift the thermal neutral zone either up or down, my data show that changing environmental conditions can bring about rapid shifts in the zone of thermal neutrality.

The upper end of the thermal neutral zone is also lowered when the bird is irradiated—bird showed signs of high temperature stress (panting) at lower air temperatures. In nature, the bird alleviates this stress by retreating to the shade, where like all birds (independent of color) it emits long wave radiation as a blackbody (*10*) and thus loses heat to the cooler surroundings. The ability of birds to take advantage of solar radiation in thermal regulating once again points out the importance of behavior in thermal regulation.

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Hormonal Termination of Larval Diapause in Dermacentor albipictus

Abstract. *The molting hormone, α-ecdysone, and an analog* Δ^7*-5β-cholestene-2β,3β,14α-triol-6-one when applied externally, terminates diapause in larvae of the winter tick,* Dermacentor albpictus. *This is the first reported hormonal termination of diapause in an arthropod other than an insect.*

Under outdoor conditions in the United States, the eggs of the winter tick *Dermacentor albipictus* (Packard) hatch during the winter or early spring months; but the larvae diapause and do not seek hosts or attach if they are placed on hosts during the subsequent spring or summer. In the laboratory, larvae exposed to a cycle of 16 hours of light, 8 hours of dark (LD 16:8) at a temperature of 27°C and 80 percent relative humidity diapause in much the same way, but comparable larvae kept in LD 8:16 for 4 weeks will attach and feed on a guinea pig or a cow (*1*).

Juvenile hormone or juvenile hormone analogs will initiate feeding activity (*2*), yolk deposition (*3*), oviposition (*4*), and morphogenetic effects (*5*) in diapausing insects. Also, molting hormones (10 μg or less per insect) will terminate diapause in several species of insects when injected (*6*). I have investigated the influence of the two major molting hormones (α-ecdysone and 20-hydroxyecdysone), an analog of molting hormone (Δ^7-5β-cholestene-2β,3β,14α-triol-6-one), and an analog of juvenile hormone (*trans,trans*-10,11-epoxyfarnesenic acid methyl ester), on the termination of larval diapause in *D. albipictus.* The insect molting hormones were dissolved in methanol (*7*). The analogs of molting hormone and of juvenile hormone were dissolved in acetone.

Groups of 25 diapausing larvae exposed to LD 16:8 from the time the female parent detached from the host were treated with either 0.1 or 1 percent solutions (1 μl) of one of the four compounds applied topically to each larva with a microapplicator. Then the larvae, placed on filter paper in a Büchner funnel, were dried by air gently pulled through the funnel. One day later the larvae were placed inside small plastic containers (*8*) attached to closely clipped guinea pigs; the percentage of attached (and feeding) larvae was determined at the end of 48 hours. Other samples of 100 diapausing larvae were each immersed in one of the same solutions for less than 15 seconds and handled in the same way as those with topically applied solution. Untreated controls from both short- and long-day photoperiods were placed on guinea pigs at the same time as the treated larvae. In other tests, the effects of the solvents on mortality and attachment were shown to be insignificant.

Treatment with either concentration of the triol compound terminated larval diapause in this tick (Table 1). Treatment with the α-ecdysone produced positive effects. The triol compound was the most effective of the four compounds tested by topical application. Immersion in a 1 percent solution of 20-hydroxyecdysone seemed to be more effective than the topical application of the same material (Table 2). The analog of juvenile hormone, *trans,trans*-10,11-epoxyfarnesenic acid methyl ester, was ineffective when applied topically, but a variable response was observed when the larvae had been immersed in it. During immersion, the compound might have entered by ingestion as well

Table 1. Comparison of the effect of hormones on termination of diapause in *Dermacentor albipictus* larvae as determined by the percentage of attachment to guinea pigs when treated topically with 1 μl per larva to 6 replicates of 25 diapausing larvae 28 days old. Some larvae died or escaped, so the percentage of attachment represents the ratio of the number of larvae that attached to the total number present and alive at the end of 48 hours.

Concentration (%)	Larval attachment (%)						
	1	2	3	4	5	6	Average
20-Hydroxyecdysone							
0.1	8	12	4	4			7
1.0	12	8	4	32	10	44	18
α-Ecdysone							
0.1	28	48	25				34
1.0	32	24					28
trans,trans-*10,11-Epoxyfarnesenic acid methyl ester**							
0.1	0						
1.0	0						
Δ^7*-5β-Cholestene-2β,3β,14α-triol-6-one*							
0.1	56	30	25	32	24	40	35
1.0	68	21	32	64	60	36	47
Long-day control							
	8	4	12	4	6	4	6
Short-day control							
	43	56	56	52	32	32	45

* Methyl-10,11-epoxy-3,7,11-trimethyl-2,6-dodecadienoic acid.

Table 2. Percentage of larval attachment to guinea pigs of 100 diapausing larvae immersed at indicated ages (days) in solutions. The percentage of attachment represents the ratio of the number of larvae that attached to the total number present and alive at the end of 48 hours.

Concentration (%)	Larval attachment (%) at day:				
	18	28	28	28	42
20-Hydroxyecdysone					
0.1	4				
1.0		36	29	21	40
trans,trans-*10,11-Epoxyfarnesenic acid methyl ester**					
0.1	8				
1.0		8	37	5	21
Δ^7*-5β-Cholestene-2β,3β,14α-triol-6-one*					
0.1	18				
1.0		20	18		44

* Methyl-10,11-epoxy-3,7,11-trimethyl-2,6-dodecadienoic acid.