THE EFFECT OF ENVIRONMENTAL TEMPERATURE AND LIGHT ON THYROID ACTIVITY AND CERTAIN METABOLIC MEASURES IN SHEEP

Thesis for the Degree of Ph. D.
MICHIGAN STATE UNIVERSITY

Hugh Edward Henderson

1958

This is to certify that the

thesis entitled

THE EFFECT OF ENVIRONMENTAL TEMPERATURE
AND LIGHT ON THYROID ACTIVITY AND
CERTAIN METABOLIC MEASURES IN SHEEP

presented by

Hugh Edward Henderson

has been accepted towards fulfillment
of the requirements for

Ph. D. degree in Animal Husbandry

H. A. Henneman
Major professor

Date 5/20/58

O-169

THE EFFECT OF ENVIRONMENTAL TEMPERATURE AND LIGHT ON THYROID ACTIVITY AND CERTAIN METABOLIC MEASURES IN SHEEP

by

Hugh Edward Henderson

AN ABSTRACT

Submitted to the School for Advanced Graduate Studies of
Michigan State University of Agriculture and
Applied Science in partial fulfillment of
the requirements for the degree of

Doctor of Philosophy

Department of Animal Husbandry

1958

Approved H. A. Henneman

ABSTRACT

THE EFFECT OF ENVIRONMENTAL TEMPERATURE AND LIGHT ON THYROID ACTIVITY AND CERTAIN METABOLIC MEASURES IN SHEEP

Hugh E. Henderson

The effect of ambient temperature and artificial light on thyroid activity and other metabolic measures in ewes was conducted from June 18, 1957 to January 18, 1958.

A total of 12 experiments involving seven ewes each was conducted in controlled temperature and light chambers. Each experiment was conducted over a period of 27 days with seven days devoted to acclimatization and 20 days to collection of data. All experimental animals were maintained in a similar environment prior to being placed on experiment and self-fed feed and water prior to and during the experimental period.

Estimates of thyroid activity for each temperature and light condition studied were obtained by thyroidal uptake or retention of I^{131}, output half-time of I^{131}, l-thyroxine secretion rate, chemical analysis of thyroidal I^{127}, and histological determination of thyroid epithelial cell height.

Estimates of thyroid activity obtained by all five methods were in very close agreement with the exception of thyroidal content of I^{127} and percent uptake of I^{131} which failed to reveal any significant difference among the various temperatures studied.

It was demonstrated that ambient temperature had a profound effect on thyroid activity, with high temperature greatly suppressing and low temperature stimulating thyroid activity.

Hugh E. Henderson

Daily body weight gains, daily feed intake per pound of body weight, daily water intake, rectal body temperature, and respiration rate were all found to be significantly affected by ambient temperature.

Ewes subjected to 12 hours of artificial light daily showed significantly greater values for thyroid activity than did ewes at 8 or 16 hours of light as measured by output half time.

Daily hours of artificial light had a significant effect on feed consumption and respiration rate, but had little or no effect on rectal body temperature, water intake, and body weight gains.

From the correlation analysis, a highly significant inverse relationship was observed between maximum uptake or retention of I^{131} at three, five or ten days after injection and output half time. These correlations demonstrated that an actively secreting thyroid was accompanied by a low uptake or retention of I^{131} and vice versa. Retention values at ten days post injection of I^{131} were more reliable estimates of thyroid activity than three day uptakes and appeared to be a reliable inverse estimate of thyroid activity in ewes at temperatures below 90° F.

THE EFFECT OF ENVIRONMENTAL TEMPERATURE AND LIGHT ON THYROID ACTIVITY AND CERTAIN METABOLIC MEASURES IN SHEEP

by

Hugh Edward Henderson

A THESIS

Submitted to the School for Advanced Graduate Studies of
Michigan State University of Agriculture and
Applied Science in partial fulfillment of
the requirements for the degree of

Doctor of Philosophy

Department of Animal Husbandry

1958

Hugh Edward Henderson

candidate for the degree of

Doctor of Philosophy

Final examination: May 13, 1958, 1:30 p.m., 103 Anthony Hall

Dissertation: The Effect of Environmental Temperature and Light on Thyroid Activity and Certain Metabolic Measures in Sheep.

Outline of Studies

Major subject: Animal Husbandry
Minor subjects: Physiology
Anatomy - Pathology

Biographical Items

Born, September 2, 1923, Clover, Virginia

Undergraduate Studies, Virginia Polytechnic Institute, 1941-1946

Graduate Studies, Virginia Polytechnic Institute, 1953-1956

Michigan State University, 1956-1958

Experience: Member United States Navy, 1943-1945, Farm Manager 1946
Assistant County Agent, 1946-1948, County Agent 1948-1951,
Assistant Professor, Virginia Polytechnic Institute, 1952,
Associate Professor, Virginia Polytechnic Institute, 1953-1956,
Graduate Assistant, Michigan State University, 1956-1958.

Member of American Society of Animal Production, Royal Order of Squanto, Sigma Epsilon, and Sigma Xi.

ACKNOWLEDGEMENTS

The author wishes to express his deepest appreciation to Dr. Harold A. Henneman, under whose guidance and supervision this work was done, for his interest, encouragement, inspiration, and help throughout the course of study.

Sincere thanks and acknowledgement go to Dr. E. P. Reineke for his constant interest, guidance, and supervision during the study. His ever willingness to offer assistance and inspiration will always be remembered.

Grateful appreciation is extended to Dr. William T. Magee for his assistance in the design and statistical analysis. Sincere thanks are expressed to Dr. C. K. Whitehair and Dr. Lois Calhoun, other members of the guidance committee, for their willing assistance, advise and encouragement. The opportunity to have worked with the entire committee and known them as a scientist, scholar, teacher and friend will always be cherished.

Sincere thanks are extended to Lee Bell, shepherd, for his assistance in caring for experimental animals and Mrs. Kay Butcher for an excellent job of typing and arranging the manuscript.

The author further thanks and is grateful to Michigan State University for financial assistance in the form of an assistantship and making experimental facilities available for the study.

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

LIST OF TABLES

LIST OF TABLES (continued)

LIST OF FIGURES

LIST OF APPENDICES

LIST OF APPENDICES (continued)

I. INTRODUCTION

It is well established that both environmental temperature and the length of daylight has a pronounced effect on the physiology of practically all of the life processes important to meat animal production.

Numerous experiments indicate that both the length of day and ambient temperature play a major role in the seasonal breeding habit of the ewe, and suggest that its action may be exerted through the pituitary-thyroid gland relationship which controls body metabolism.

Since previous research indicates that thyroid activity in the ewe varies from one season of the year to another, it is necessary that reliable estimates of thyroid activity be made at various controlled ambient temperature and light conditions in order to intelligently adjust activity estimates made at various seasons in the year for comparative purposes. Furthermore, if thyroid therapy is a factor in overcoming summer sterility in the ram and anestrus in the ewe, it is necessary to have reliable estimates of normal thyroid activity at the various environmental temperature and light conditions.

This investigation has been designed in order to gain more basic information on the normal thyroid activity of sheep under controlled ambient temperature and light conditions and the interrelationship of thyroid activity to certain metabolic activities in the ewe.

With a clearer understanding of the effect of ambient temperature and length of daylight on thyroid activity, a more intelligent approach can be made toward extending the breeding season of sheep and a clearer appraisal made of the effects of thyroid activity on reproductive performance and producing ability of the ewe.

II. OBJECTIVES

1. To determine the effect of controlled ambient temperature and artificial light conditions in ewes on thyroid activity as measured by:
    a. Uptake of I^{131}
    b. Turnover rate of I^{131}
    c. 1-Thyroxine secretion rate
    d. Thyroid content of I^{127}
    e. Thyroid epithelial cell height
2. To determine the effect of controlled ambient temperature and artificial light conditions in ewes on:
    a. Body weight gains
    b. Feed consumption
    c. Water consumption
    d. Respiration rate
    e. Rectal body temperature
3. To correlate ambient temperature and artificial light conditions in ewes on certain metabolic and physiological functions.

III. REVIEW OF LITERATURE

Following the classical work of Magnus-Levy (1895) who observed that the feeding of thyroidal materials caused an increase in the oxygen - carbon dioxide exchange, it has been well established by numerous investigators that the thyroid hormone regulates the rate of metabolic exchange in mammals. Most of the early estimates of thyroid activity were based on the measurement of carbon dioxide by respirometers as reported by Mørch (1929) and Teitelbaum and Horme (1941).

Many investigations have been conducted to determine the role that the thyroid hormone plays in the various life processes and in particular, growth and reproduction. Furthermore, the effects of environment on thyroid function and its interrelationship to other endocrine functions have received the attention of many investigators in recent years.

The role of thyroid hormone in reproductive physiology of the female has been reviewed quite completely by Reineke and Soliman (1953). They concluded that there is a reciprocal balance between the hormones of the pituitary, the ovary, and the thyroid. Through the influence of estrogen on pituitary thyrotrophin, the thyroid undergoes rhythmic fluctuations in secretion rate that in turn regulate the output of gonadotrophins and also modify their action on the ovary.

Bogart and Mayer (1946) concluded that the thyroid gland appears intimately concerned with spermatogenic activity of testes in sheep and that the failure of thyroxine to affect semen volume, or motility ratings in rams with lowered fertility during the period of high summer temperature indicates that the thyroid affects the spermatogenic tissue of the testes and has little or no effect upon the interstitial tissue or the accessory organs which are dependent on androgens.

Maqsood (1950) reported that mild hyperthyroidism stimulated spermatogenesis and increased secretory activity of interstitial tissue as judged by growth and activity of accessory organs and sexual behavior of growing mice, rabbits and rams. Thyroidectory and prolonged thiouracil feeding interferred with spermatogenesis and increased fibrinous tissue in the interstitial spaces.

Jaap (1933), Martinez Campos (1947), and Wheeler and Hoffman (1948), working with domestic fowl and Meites and Chandrashaker (1948), working with rats and mice, reported that milk hyperthyroidism increased spermatogenesis.

Organon (1936) cited evidence that thyroid therapy was effective in some cases of human male and female sterility.

Petersen <u>et. al.</u> (1941) found that the administration of thyroprotein to hypothyroid cattle improved both sexual libido and fertility.

Masson (1947) showed that the response of the accessory sex glands in castrated male mice to testosterone was increased by thyroxine administration.

Black <u>et. al.</u> (1950) reported that the addition of testosterone and thyroprotein increased semen volume in rams during the summer months.

Warwick et. al. (1948) concluded that during the summer months semen produced by rams receiving low levels of thyroprotein was slightly superior to controls.

Smelser (1939) reported that thyroidectomy and administration of excessive quantities of thyroxine resulted in functional reproductive abnormalities.

Oloufa (1951) reported that high ambient temperature greatly reduced semen volume, motility, sperm concentration, and percent normal sperm in rabbits and that continuous heat had a more prouounced effect than intermittent heat. The addition of thyrotrophin under continuous heat caused a further reduction of fertility but under intermittent heat, it improved fertility.

Berliner and Warbritton (1937) placed rams in a hot room during the winter period and brought about a stoppage of spermatogenesis. Rams which were thyroidectomized were brought back to fertility by injections of thyroxine. Fertility of rams with intact thyroid glands was greatly improved by injections of thyroxine. Biological assay of the pituitaries showed that rams with poor semen quality were also low in thyrotrophic hormone.

Reineke et. al. (1941) reported that following thyroidectomy of goats, there was a reduced content of pituitary gonadotrophins.

VanDyke and Chen (1933) found that hypothyroidism in rabbits causes a reduced pituitary content of gonadotrophins which was also true for animals thyroidectomized.

Numerous investigations have clearly indicated that thyroid function was markedly augmented during exposure of mammals to reduced environmental temperature and retarded by elevated environmental temperature; however, little data has been reported on the quantitative thyroid secretion rate of mammals at controlled high and low environmental temperatures.

Some of the earliest evidence of increased thyroid activity at low environmental temperatures was reported by Cramer (1916), Seidell and Fenger (1912), Mills (1918), and Kendall and Simonsen (1928).

Dempsey and Astwood (1943) observed that thyroid secretion rate in rats increased markedly at low environmental temperatures and was depressed at high temperatures.

Mixner et. al. (1944) reported that the thyroid of the chick responded in a similar manner and also Reineke and Turner (1945) observed a seasonal trend in the thyroid secretion rate of young chicks.

A pronounced decline in thyroid secretion rates of mice were reported by Hurst and Turner (1948) when the temperature was increased from 80° to 87° F.

Turner (1948) reported a seasonal trend in thyroid secretion rate in hens and a pronounced decline in the secretion rate of older hens.

Maqsood and Reineke (1950) observed a ten-fold reduction in tolerance of mice to thyroprotein feeding when the environmental temperature was raised from 24° to 30° C. They suggested that tolerance limits for thyroid stimulation were determined by the temperature regulating capacity.

Half-time turnover rates of extrathyroidal I^{131} thyroxine were found to average 25 hours in shorn and 38 hours in unshorn sheep by Freinkel and Lewis (1957) when both groups were exposed to winter temperatures in Great Britain.

Henneman et. al. (1955) reported thyroid secretion rates in ewes to be lowest during summer months and highest during winter months and that pregnancy had little effect on secretion rate.

Since the advent of radioactive iodine (I^{131}) much research has been conducted in order to improve estimates of thyroid activity in mammals and more recently, in the live intact animal.

Perry (1951) measured the rate of loss of I^{131} from the thyroid gland of the rat with an external counter and determined an index of the secretion of thyroid hormone. By checking the validity of the index against the effect of thyrotrophic hormone, goitrogens and thyroxine on the rate of loss of I^{131}, a relationship was established between dose of thyroxine and degree of inhibition of thyroid hormone secretion.

Henneman et. al. (1955) measured thyroid secretion rate in ewes by injecting graded dosages of 1-thyroxine following maximum uptake of I^{131}. Counts were taken at the end of each 3 day 1-thyroxine injection period and percentage of previous count computed. Using percentage of previous count and level of thyroxine injected, a straight line was computed by regression analysis. The point at which the line crossed 100 percent of previous count was assumed to be the secretion rate of the ewe in question.

Reineke and Singh (1955) using essentially the same technique as that outlined by Henneman, were able to determine the thyroid secretion rate in rats. Values compared very closely with those obtained by the goitrogen technique.

Using the same technique, thyroid secretion rates have been determined for dairy cattle by Lewis et. al. (1955) and Premachandra et. al. (1957), and for goats by Flamboe (1958).

Percent uptake of I^{131} by the thyroid gland as an indicator of thyroid secretion rate is a debated point by many investigators at the present time.

Reineke et. al. (1956) and Chai et. al. (1957), in studying I^{131} uptake and output rates in inbred mice, found a reciprocal relationship between percentage uptake and output rate; a high uptake was accompanied by a low output rate and vice versa. They theorized that the low uptake - high output rate relationship meant that there was either a larger thyroidal iodine pool prior to injection or that the rate of uptake was more rapidly overtaken by the rate of discharge in the rapid output rate group.

The data collected in this study agrees with that of Reineke and Chai; however, frequent reference has been made in the literature that a high uptake of I^{131} was positively associated with a rapid turnover rate and a low uptake was associated with a slow output.

The effect of ambient temperature on physiological responses in mammals has received the attention of many investigators in recent years; however, most of the studies in the ewe and ram have been in relation to reproductive performance.

McKenzie and Phillips (1933) concluded that temperature seemed to cause no significant difference in the length of time required for ewes to come into estrus in a trial covering a ten day period of time in August with one group under natural conditions and the other group confined to an iced cellar.

Yeates (1953) concluded that high temperature was apparently without effect on the incidence of estrus in ewes but was detrimental to satisfactory gestation. When ewes were treated with 7 hours of 107° F. heat daily from breeding until parturition, there was a fifty percent reduction in number of lambs born over the controls which received no heat treatment.

Dutt and Bush (1955) observed that ewes placed in a cold chamber at 48° F. with natural light on May 26 came into estrus 48 day later on the average, as compared to ewes in a hot chamber at 88° F. which came into estrus 94 days later. Rectal body temperatures for the two groups were 102.0° F. and 103.4° F. with respiration rates of 28/m and 150/m in the cold and hot chambers respectively. Rams in the cold chamber averaged 1.9 services per ewe conception as compared to 5.3 services per ewe conception for the hot chamber rams.

Dutt <u>et. al.</u> (1956) concluded that fertility and normalcy of ova in ewes exposed to elevated environmental temperatures were more severely affected than survival of the young embryo. Shearing the ewe before exposure to the elevated temperature modified the detrimental effects.

Green (1940) observed that semen quality in rams decreased from January to May, June and July ejaculates were quite inferior, July to October showed a rapid increase toward high quality, and the highest quality was obtained from October to January.

Foote et. al. (1957) observed that at high ambient temperatures, testes temperature of rams increased at a faster rate than rectal temperature.

Lee (1945) observed a very low rate of lay in laying hens at high environmental temperatures and concluded that 80° F. appeared to be the critical temperature.

Casady (1953) observed that the duration of exposure to high temperatures in dairy bulls had a tremendous effect on fertility levels and that subjection of bulls to 85° to 90° F. for five weeks may interfere with spermatogenesis, reduce sperm concentration and motility and increase the number of abnormal sperm similar to effects noted during exposure to 100° F. for two weeks.

Casady et. al. (1956) in experiments with young dairy bulls at chamber temperatures of 60° to 95° F. observed that correlations between rectal temperature and respiratory rate, rump skin temperature and scrotal skin temperature were lower than the correlation between chambem temperature and the same responses. On the other hand, water consumption was more closely related to rectal temperature than chamber temperature.

Field studies of Johnston and Branton (1952) indicated significant correlations between body temperature and ambient temperature only when the ambient temperature was within 40° to 60° F. and 70° to 80° F. intervals. Respiration rate was significantly correlated with ambient temperature and humidity, except when maximum temperatures were within the 80° to 85° F. and 85° to 90° F. intervals. Pulse rate was significantly correlated with mean daily temperature within the 85° to 90° F. interval. Later investigations by Johnston and Branton (1953) and Johnston <u>et. al.</u> (1954) showed that only respiration rate was consistently related to climatic conditions, with absolute humidity and mean environmental temperature being most highly correlated with respiratory responses.

McDowell <u>et. al.</u> (1953) with chamber studies on respiratory activity as an index of heat tolerance concluded that respiration rate was not significantly correlated with rectal temperature under the conditions of their experiment. Similar conclusions were drawn by [illegible] and Findlay (1955a, 1955b) from results of chamber studies with bulls.

Fletcher and Reid (1953) in studying heat tolerance of feeder lambs on pasture in Mississippi, found that shorn lambs showed rectal temperatures of 104.6° F. as compared with unshorn lambs of 105.4° F.

Miller and Monge (1946) observed that body temperature and respiration rate in sheep were very highly correlated with ambient temperature.

In experiments with swine subjected to chamber temperatures from 40° to 115° F., Heitman and Hughes (1949) observed that as air temperature increased, rectal temperature and respiration increased and pulse rate decreased. Feed consumption decreased as air temperature increased. Under their experimental conditions, rate of gain was greatest and the amount of feed required to produce 100 pounds of gain was least at an average temperature of approximately 75° F. for hogs weighing 70 to 144 pounds and approximately 60° F. for hogs weighing 166 to 200 pounds. As the air temperature was increased or decreased above or below these averages, rate of gain declined and utilization of feed was lowered. At 96° F. a rise in relative humidity from 30 to 94 percent produced rapid distress in hogs weighing over 200 pounds, and the respiration rate and body temperature increased rapidly.

Heitman <u>et. al.</u> (1951), in a later study with pregnant sows, found that increasing ambient temperature markedly elevated respiratory rate and rectal temperature. Feed and water consumption were greatly lowered at temperatures above 95° F. No evidence was accumulated that indicated that rise in body temperature under these conditions would cause abortion of a normal litter; however, Ragsdale <u>et. al.</u> (1949) reported that two dairy cows aborted 4.5 and 6 month fetuses when exposed for 27 hours to a temperature of 100° F.

Ragsdale <u>et. al.</u> (1953) presented tabular and graphic data on milk production and composition, feed and water consumption, and body weight in Holstein, Brown Swiss, Jersey and Brahman cows at low and high relative humidities at various temperatures. They showed that below 75° F.

atmospheric temperature, the effect of relative humidity on the above processes is not significant. The effect of humidity increases with increasing temperature above 75° F.

Robinson and Lee (1947) observed from experiments with hens, sows, and ewes on high and low planes of nutrition that under hot conditions, the reactions of animals on the high plane of nutrition were significantly greater than animals on a low plane of nutrition. In another series of experiments where animals were fed rations varying in protein from 5 to 28.5 percent and exposed to a critically hot atmosphere for seven hours, in no case was any evidence obtained that a high proportion of protein had any significant effect upon the reactions of animals to heat.

Investigations on the effect of length of day or hours of artificial light on physiological responses in mammals have been devoted almost exclusively to reproduction aspects with little or no data on growth rate, feed and water consumption, body temperature, and respiration rate.

Bissonnette (1932), Marshall (1940), and Hart (1950), all working with ferrets, observed that the time of onset of the breeding season varied with the intensity of light and that the frequency of light to dark was the important factor rather than the amount. The ratio of 2 hours of light to 1 hour of darkness seemed to be about the desired ratio and a reverse ratio caused the animals to go into anestrus.

Hammond (1944) pointed out that the breeding season in sheep normally occurs at about the shortest day of the year and that ewes bred the first half of the season had more twin lambs than those bred in the last half.

Sykes and Cole (1944) observed that when the plane of light was increased daily until 3 hours were added in March, and then decreased light 1 hour per week until May, five of eight ewes were bred and lambed five months previous to the normal time.

Yeates (1949) concluded that temperature had no effect on bringing ewes into estrus; whereas, decreasing the plane of light in the spring brought about estrus and increasing the plane of light in the fall prevented estrus. He concluded that estrus occurred 14 to 16 weeks after ewes were put on decreasing light and estrus ceases 14 to 16 weeks after increasing the plane of light.

Hart (1950) concluded that a gradual decrease of light was not necessary to bring about estrus in ewes but required only a ratio of 1 part light to 2 parts dark.

Hafez (1950), (1951), (1952) observed that continuous light as well as 16 hours of light and 8 hours of darkness brought about anestrus in ewes. Eight hours of light and 16 hours of darkness was effective in bringing ewes into estrus.

Mercier and Salisbury (1947a) studied the records of 125,000 cows artificially bred to 71 bulls and observed that fertility of bulls was highly correlated with length of daylight. One to two months of increasing light was necessary before the effect of daylight reached its maximum.

Mercier and Salisbury (1947b) also observed a significant correlation between hours of daylight and fertility level of bulls as measured by services per conception. Lowest fertility was observed in winter and spring, and highest in summer and fall.

IV. METHODS AND PROCEDURE

In order to control ambient temperature and light conditions, two temperature and light control chambers were used in this study. Animals were confined to 3 by 6 foot individual pens within the chambers in order to obtain individual feed and water consumption records.

The cold chamber consisted of a reconditioned meat cooler measuring 10 feet wide, 20 feet long and 12 feet high. The chamber was cooled by recirculating air over cooling coils with electric blowers. For each of the experiments, temperature was maintained within plus or minus one degree of the temperature reported. Even with the aid of a dehumidifier, it was impossible to reduce the relative humidity in the cold chamber to that of the hot chamber. A range of 76 to 84 percent relative humidity was maintained in the cold chamber. Ragsdale <u>et. al.</u> (1953) reported that high relative humidity did not measurably affect metabolic functions in dairy cattle unless ambient temperature was in excess of 75° F. It was assumed that the high humidity in the cold chamber did not alter the experimental results.

All natural daylight was excluded from the chamber and artificial light was provided by four 300 watt light bulbs suspended 8 feet above the floor. An electric time switch controlled the number of hours the lights were on during each 24 hour period. The reported hours of artificial light in all cases was a continuous amount of time out of each 24 hour period.

The hot chamber was of masonry construction and measured 20 feet wide, 20 feet long and 16 feet high. The chamber was heated by recirculating air over steam coils with an electric blower and temperature was maintained within plus or minus one degree of the reported temperature. Relative humidity varied from 60 to 70 percent throughout the experimental period and a dehumidifier was not used. All natural light was excluded from the chamber and artificial light was provided by six 300 watt light bulbs suspended 8 feet above the floor. Lights were controlled in the same manner as outlined for the cold chamber and the intensity of light was approximately the same for both chambers.

The original range of temperatures selected to be studied were 40°, 55°, 70°, and 85° F. Since the first series of experiments were run at 55° and 85° F. and little difference was observed in the various physiological responses studied, it was decided to substitute 90° F. for the 70° F. group. The cooling capacity of the cold chamber was not great enough to maintain the 40° F. temperature; therefore, 50° F. was substituted in its place.

The experimental animals consisted of 24 blackface California ewe lambs and 12 native fine wool yearling ewes. The California lambs were approximately 4 to 5 months of age and averaged 70 pounds when they arrived on April 15, 1957. The native yearlings were approximately 6 to 7 months older and averaged 75 pounds.

Both groups were shorn and placed on pasture where they remained until two weeks prior to the beginning of the experiment on June 18, 1957.

At this time both groups were confined to a large pen within a masonry building with heat available where temperature was maintained at approximately 70° F. (plus or minus 5°) with natural light conditions. This also served as a holding pen for animals between experiments which insured that all animals were subjected to the same environment prior to being placed on experiment and helped eliminate any pre-experimental treatment effect from altering the experimental data.

Throughout the course of the experimental period, all animals were given feed, water and trace mineral salt ad. lib.

In order to eliminate wastage and to insure accurately measured feed consumption, the entire ration was pelleted into one-fourth inch pellets. It contained the following ingredients:

1600 pounds	ground alfalfa hay
390 pounds	yellow corn
10 pounds	dicalcium phosphate
10 pounds	trace mineral salt
5 pounds	Vitamin a pre-mix (5 million units)
2 pounds	Aurofac 10
1 pound	Vitamin D_2 (625,000 units)
2018 pounds	Total

Each experiment included six California ewe lambs which received I^{131} and were again used in succeeding experiments and one native yearling which did not receive I^{131} and was slaughtered at the end of each experiment for histological study of endocrine glands and chemical determination of thyroidal iodine. Data were collected on both the California lambs and native yearlings for weight gains, feed consumption, water consumption, respiration rate, and rectal body temperature. Only the California ewe lambs were used to collect data on I^{131} uptake and turnover rate and l-thyroxine secretion rate. Both groups averaged approximately 80 pounds at the beginning of the experimental period on June 18, 1957 and 140 pounds at the termination on January 18, 1958.

Following each experiment, the California ewes were given a 30 day rest in order to allow any residual I^{131} to decay and to prevent any carry-over effects from one experiment to another. As a further check against carry-over effects, a stratified system of randomization was used in alloting animals to the hot and cold chambers. Analysis of variance showed that there were no carry-over effects.

Since experiments were being conducted concurrently in the hot and cold chambers, a total of 12 California ewes were on experiment at all times and 12 were being rested in the holding pen for succeeding experiments.

At the beginning of each experiment, animals were randomly assigned to individual pens within the chambers and allowed 7 days to become acclimated to the respective temperature and light condition. On the seventh day the animals were weighed and injected subcutaneously on the medial side of the right rear leg with 50 microcuries of I^{131}. Individual feed and water records were kept for a period of 20 days along with daily respiration rate and rectal temperature every other day. Animals were again weighed at the termination of the 20 day experimental period and the native yearling was slaughtered.

External I^{131} counts were taken over the area of the thyroid beginning 24 hours after the time of injection and continued daily until maximum uptake of the injected I^{131} had been reached.

For output turnover rate studies, counts were taken every 48 hours after maximum uptake of I^{131} and continued until five such counts had been made. The counting technique as outlined by Henneman et. al. (1955) was used throughout the study. All I^{131} counts were made by a scintillation counter (Nuclear Chicago, model number DS-1) and a count rate meter (Nuclear Chicago, model number 1620).

For 1-thyroxine secretion rate studies, 150 microcuries of I^{131} were injected instead of the usual 50 microcuries in order that sufficient count would be available following turnover rate determinations. A count was taken 3 days prior to the last count used for the turnover rate determination which was considered as zero time. Counts were taken every third day thereafter throughout the 1-thyroxine injection period. Again, the technique outlined by Henneman et. al. (1955) was used for 1-thyroxine injection procedures and estimates of secretion rate.

All data were collected during the period of time when the lights were on in the respective chambers and the chambers were not entered during the period of darkness.

Immediately following slaughter of the native ewe which did not receive I^{131}, the pituitary, thyroid, adrenals, and ovaries were dissected free of adhering tissue in a saline solution and weighed to the nearest milligram. The ovaries, adrenals and one lobe of the thyroid were fixed in 10 percent formalin, sectioned in paraffin and stained with Harris Haemotoxylin-eosin. The remaining lobe of the thyroid and pituitary were immediately frozen for later iodine determination and biological assay.

Chemical iodine determination of frozen thyroids were made by using the procedure of Reineke _et. al._ (1945) as reproduced in part in appendix S.

V. RESULTS AND DISCUSSION

A. Effect of Ambient Temperature and Artificial Light on Thyroidal Uptake of I^{131}:

Counts were taken over the area of the thyroid beginning 24 hours after subcutaneous injection of 50 microcuries of I^{131} and continued every 24 hours thereafter until each animal had reached its peak uptake of I^{131}. Each count was compared with the count of a 5 microcurie I^{131} standard prepared on the day of injection and the percent uptake of injected dosage was computed.

Since a large number of researchers have interpreted a high I^{131} uptake by the thyroid and the speed at which it is taken up to be highly correlated with a high output of l-thyroxine, this experiment was designed to measure the effects of ambient temperature and artificial light on both the percent and rate of uptake of I^{131} by the thyroid and their relation to output rate.

The results of one day percent uptakes are shown in table 1. Analysis of variance showed that significant differences ($P < .01$) existed among both temperature and light conditions. Correlation analysis revealed no significant correlation between one day percent uptake and both ambient temperature and turnover rate of I^{131} one-half time.

The results of three day percent uptakes are shown in table 2. Analysis of variance again showed a significant difference ($P < .01$) among light conditions but no significant difference among temperatures; however, there was a significant interaction ($P < .05$) between temperature and

Table 1

One Day Percent Uptake of I^{131} by the Thyroid Gland in Ewes Under Controlled Ambient Temperature and Artificial Light Conditions[1]

Hours of Artificial Light	Ambient Temperature 50° F.	55° F.	85° F.	90° F.	Average
8	9.32	11.62	10.25	4.63	8.63*
12	5.85	7.52	6.43	5.91	6.43
16	5.87	9.22	9.15	6.67	7.73
Average	7.01	9.02**	8.61*	5.74	7.59

[1]The value reported for each temperature and light condition is an average of six ewes.
*Significantly different from the least value
**Significantly different from the two least values

Table 2

Three Day Percent Uptake of I^{131} by the Thyroid Gland of Ewes Under Controlled Ambient Temperature and Artificial Light Conditions[1]

Hours of Artificial Light	Ambient Temperature 50° F.	55° F.	85° F.	90° F.	Average
8	14.41	9.89	10.39	10.15	11.21*
12	10.07	10.02	9.27	8.84	9.55
16	9.14	13.49	14.78	12.34	12.44
Average	11.20	11.13	11.48	10.44	11.07

[1]The values reported for both temperature and light condition is an average of six ewes.
*Significantly different from the least value

light. There was no significant correlation between three day percent uptake and ambient temperature or light conditions; however, there was a significant correlation of .28 ($P<.05$) between turnover rate of I^{131} one-half time and three day percent uptake of I^{131}.

There was no significant difference among temperatures for maximum percent uptake as shown in table 3. Again there were significant differences ($P<.01$) among light conditions. There was also a significant interaction ($P<.05$) between temperature and light with the greatest uptake at 85° F. and 16 hours of light. Again there was a significant correlation of .41 ($P<.05$) between maximum percent uptake and turnover rate of I^{131} one-half time.

Table 3

Maximum Percent Uptake of I^{131} by the Thyroid Gland in Ewes Under Controlled Ambient Temperature and Artificial Light Conditions[1]

Hours of Artificial Light	Ambient Temperature				
	50° F.	55° F.	85° F.	90° F.	Average
8	15.18	11.03	12.33	11.38	12.48*
12	10.64	10.13	9.56	9.30	9.90
16	9.94	14.70	17.96	12.88	13.87*
Average	11.92	11.95	13.28	11.19	12.08

[1]The value reported for each temperature and light condition is an average of six ewes.
*Significantly different from the least value

Percent uptake zero time (table 4) was determined by extrapolating the output turnover rate regression line back to zero time. This is interpreted to indicate what the percent uptake would have been had not the thyroid gland been putting out I^{131} in the form of 1-thyroxine during the time in which I^{131} was being taken up from the blood stream. Analysis of variance again showed no significant difference among temperatures. A significant difference ($P<.01$) existed among light conditions and a significant interaction ($P<.05$) between temperature and light. Again the greatest uptake value was observed at 85° F. and 16 hours of light. There was no significant correlation between zero time percent uptake and output turnover one-half time.

Table 4

Zero Time Percent Uptake of I^{131} by the Thyroid Gland of Ewes Under Controlled Ambient Temperature and Artificial Light Conditions[1]

Hours of Artificial Light	Ambient Temperature				
	50° F.	55° F.	85° F.	90° F.	Average
8	25.32	14.46	14.29	12.88	15.23*
12	14.63	11.94	11.55	9.58	11.92
16	11.93	17.67	21.17	16.74	16.87*
Average	15.29	14.69	15.67	13.07	14.68

[1]The value reported for each temperature and light condition is an average of six ewes.
*Significantly different from the least value

There was little difference among temperatures for day of maximum percent uptake as shown in table 5. Again there was a significant difference ($P<.01$) among light conditions and a significant interaction ($P<.01$) between temperature and light.

Table 5

Day of Maximum Percent Uptake of I^{131} by the Thyroid Gland in Ewes Under Controlled Ambient Temperature and Light Conditions[1]

Hours of Artificial Light	Ambient Temperature				
	50° F.	55° F.	85° F.	90° F.	Average
8	4.0	3.8	4.3	4.2	4.08*
12	3.8	3.0	3.0	2.7	3.13
16	3.2	4.0	4.0	3.3	3.63*
Average	3.67	3.61	3.78	3.39	3.61

[1]The value reported for each temperature and light condition is an average of six ewes.
*Significantly different from the least value

In all cases, hours of artificial light significantly affected percent uptake of I^{131} by the thyroid with a non-linear relationship between hours of artificial light and percent uptake. Ewes on 12 hours of artificial light had a lower percent uptake than did either the 8 or 16 hour group and reached their maximum uptake in a shorter period of time.

This may seem to be in conflict with Terry's data (1951) who reported that ewes under continuous darkness had a higher uptake of I^{131} than did ewes under continuous light and Puntriano and Meites (1951) who also reported that rats under continuous darkness had a higher uptake of I^{131} than did rats under continuous light. An accurate comparison cannot be made since these studies did not include continuous light and continuous darkness.

Since an inverse relationship was obtained between maximum percent uptake of I^{131} and thyroid activity as measured by output turnover rate one-half time of I^{131} ($r = .41$, $P < .05$). These data may be interpreted to mean that both 8 and 16 hours of artificial light represented more stress than 12 hours of light. Reineke et. al. (1956) and Chai et. al. (1957) also observed an inverse relationship between I^{131} uptake and l-thyroxine secretion rate in inbred strains of mice.

Except at the one day interval, there was little or no difference in I^{131} uptake at any of the temperatures studied. It seems clean that any relationship that might exist is not direct and simple.

B. Effect of Ambient Temperature and Artificial Light on Thyroidal Output Turnover Rate of I^{131}:

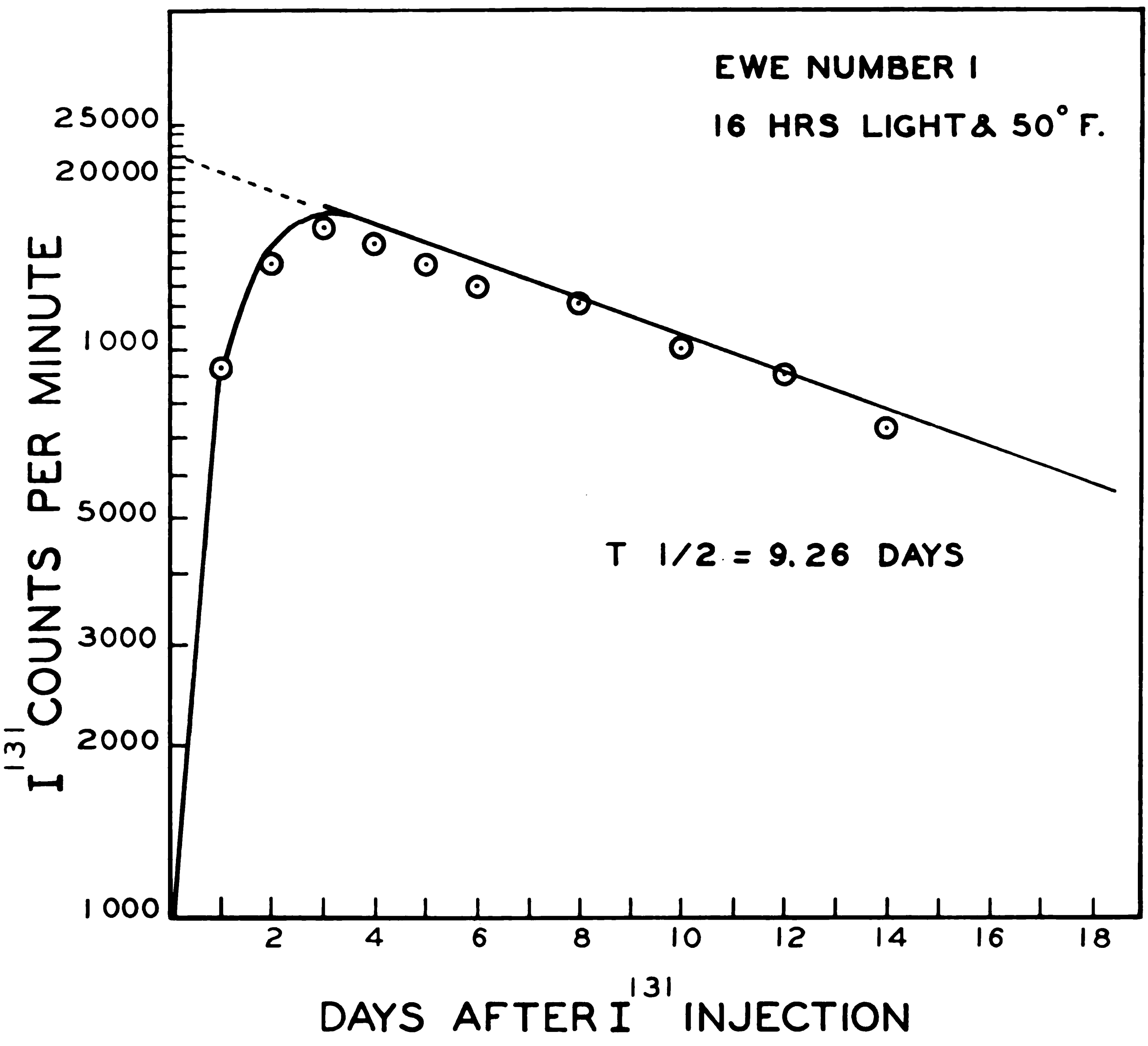
Following maximum uptake of I^{131}, counts were taken every 48 hours over the area of the thyroid until five such counts had been taken to estimate turnover one-half time of I^{131} by the thyroid. Using the log of the count against time in days, the slope of the output line was determined by linear regression. A typical uptake-output curve is shown in figure 1.

Since iodine is a necessary part of the l-thyroxine molecule, it was hoped that turnover rate would prove to be a sensitive measure of thyroid activity; however, experimental proof is lacking. Although the work of Perry (1951) and Reineke and Singh (1955) indicates that subcutaneous injection of graded doseages of l-thyroxine and the prevention of disappearance of I^{131} is perhaps the most sensitive measure of thyroid activity available, it was not used except in the last experiment due to the high level of injected I^{131} required which would possibly injure the thyroid if repeated every 30 days as required in this series of experiments.

The effect of ambient temperature on turnover one-half time of I^{131} are shown in table 6. Since intra-class correlation and regression coefficients are the most accurate estimate for a group of animals, all group estimates of turnover one-half time were arrived at by this method. In order to compare turnover at the various temperature and light conditions, the correlation coefficients were converted to a z statistic and a

FIGURE I

TYPICAL UPTAKE-OUTPUT CURVE OF I^{131} BY THE THYROID GLAND OF SHEEP



t test used to determine the level of significance. Computation procedures were taken from Snedecor (1950).

Table 6

Effects of Ambient Temperature on Turnover Rate One-half Time of I^{131} by the Thyroid in Ewes

Ambient Temperature	df	r	Level of Significance	b	Estimated Turnover Rate in Days
50° F.	89	-.91	.01	-.02409	12.496
55° F.	87	-.85	.01	-.02302	13.077
85° F.	83	-.87	.01	-.02046	14.713
90° F.	94	-.80	.01	-.01798	17.742*

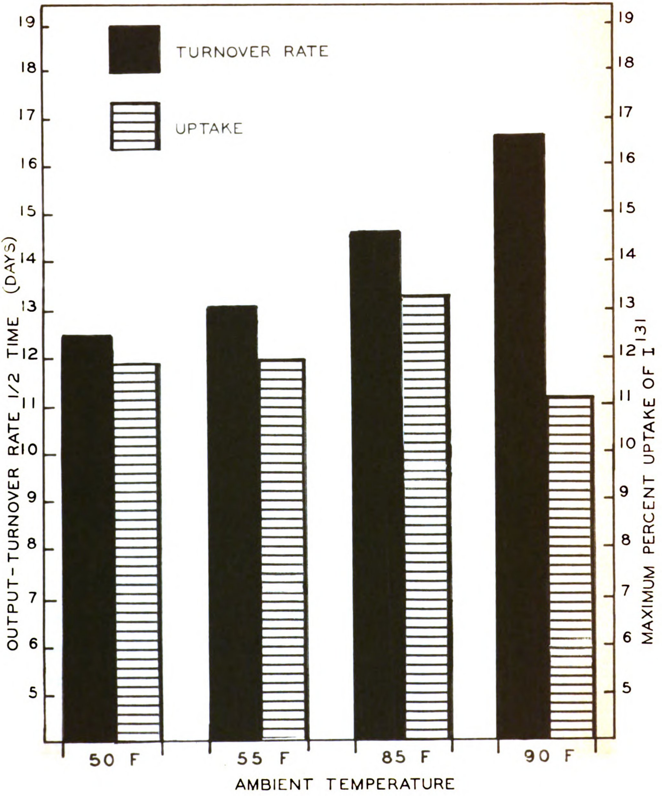
*Significantly different from the least value

Turnover one-half time at 90° F. was significantly greater ($P<.01$) than turnover at 50° F., and was not significantly different than turnover at 55° F. ($P<.25$) or 85° F. ($P<.12$). Turnover at 85° F. was not significantly different from 50° F. ($P<.18$) nor 55° F. ($P<.60$). Also 55° F. was not significantly different ($P<.30$) from 50° F. A significant correlation of .28 ($P<.05$) was obtained between turnover one-half time of I^{131} and ambient temperature and the relationship appears to be curvilinear within the temperature range studied. A graphic expression of uptake and output turnover for the respective temperatures is shown in figure 2.

Assuming that a fast turnover rate indicates a more active secreting thyroid gland, these data agree with a vast amount of literature which demonstrates that thyroid secrection rate is stimulated by low environ-

FIGURE 2

MAXIMUM PERCENT UPTAKE AND TURNOVER RATE OF I^{131} BY THE THYROID GLAND IN EWES UNDER CONTROLLED AMBIENT TEMPERATURE



mental temperature and is depressed by high environmental temperatures. Some of the more classical studies are those of Henneman et. al. (1955) who reported that the lowest l-thyroxine secretion rate in ewes occurred during July, the hottest month of the year, and Hurst and Turner (1948) who reported that high ambient temperatures caused a pronounced decrease in thyroid secretion rate in mice. Also Dempsey and Astwood (1943) reported a three fold difference in thyroid secretion rate of rats between 25° C. and 35° C.

The effects of artificial light on output one-half time of I^{131} are shown in table 7 and graphically illustrated in figure 3.

Table 7

Effects of Artificial Light on Turnover Rate One-half Time of I^{131} by the Thyroid in Ewes

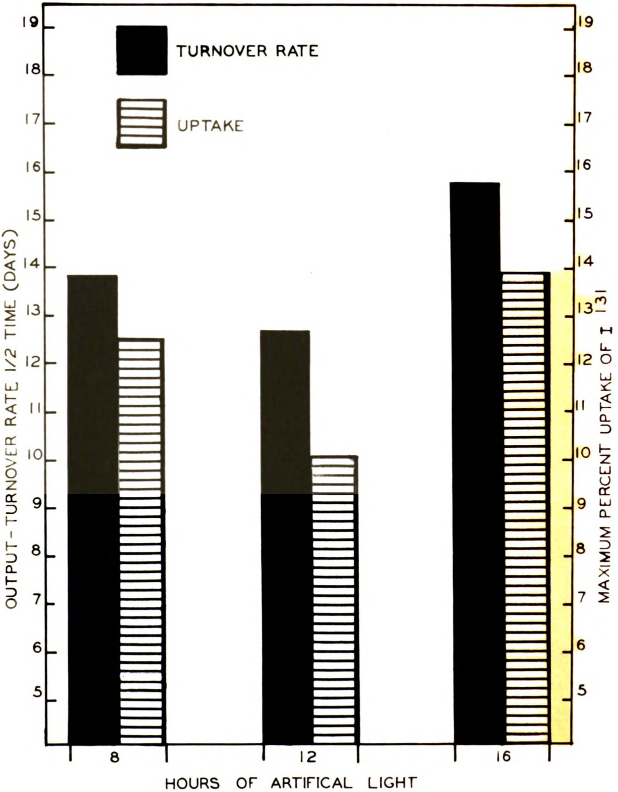
Hours of Artificial Light	df	r	Level of Significance	b	Estimated Turnover Rate in Days
8	120	-.84	.01	-.02182	13.796*
12	112	-.91	.01	-.02396	12.564
16	121	-.84	.01	-.01914	15.728*

*Significantly different from the least value

Turnover one-half time at 12 hours of artificial light was significantly lower ($P < .02$) than at 8 hours of light and 16 hours of light. Again, as was the case with uptake of I^{131}, the relationship between hours of artificial li ht and turnover rate was non-linear with both 8 hours of light and 16 hours of light depressing thyroid activity. The

FIGURE 3

MAXIMUM PERCENT UPTAKE AND TURNOVER RATE OF I^{131} BY THE THYROID GLAND IN EWES UNDER CONTROLLED ARTIFICAL LIGHT



author is at a loss to explain this relationship and recognizes the need of extending the light conditions before final conclusions can be drawn.

C. Effect of Ambient Temperature and Artificial Light on l-Thyroxine Secretion Rate:

Using the procedure of Henneman et. al. (1955), immediately following the turnover rate study on the 50° F. and 90° F. group of ewes at 8 hours of artificial light (the last experiment conducted), graded dosages of l-thyroxine were injected subcutaneously daily for a period of three days at each dose level and a count taken over the area of the thyroid. The dosage level of l-thyroxine was increased at the end of each three day period until five levels had been injected and counts obtained. Percent of previous count was computed for each dosage level and secretion rate was estimated for each individual ewe by linear regression using milligrams of l-thyroxine per 100 pounds of body weight injected daily as the x variable and percent of previous count as the y variable. The point at which the regression line intersected 100 percent of previous count was assumed to be the daily l-thyroxine secretion rate per 100 pounds of body weight of the animal in question.

Intra-class correlation and regression coefficients were used to estimate secretion rates for the 50° F. and 90° F. groups with the results shown in table 8. The t test revealed a significant difference ($P < .01$) between secretion rate of the 50° F. and 90° F. groups as was shown by turnover rate for the same groups. A correlation of -.27 between l-thyroxine secretion and turnover rate approaches significance ($P < .10$) and perhaps would have been significant had the study included all 72 animals instead of only 12. Again, as was the case with turnover rate, a significant correlation of -.60 ($P < .05$) between l-thyroxine secretion rate and ambient temperature was obtained. The daily secretion rate of .035 milligrams per 100 pounds of body weight for the 90° F. group agrees very closely with the value of .040 milligrams daily reported for ewes during the month of July by Henneman et. al. (1955).

Table 8

Estimated Daily 1-Thyroxine Secretion Rate of Ewes at Controlled Ambient Temperature and Artificial Light Conditions

Ambient Temperature	df	r	Level of Significance	b	Estimated Daily Secretion Rate in mg. Per 100 lbs. Body Weight
50° F.	25	.74	.01	139.14	.122*
90° F.	18	.43	.06	403.33	.035

*Significantly different from the least value

These data are further evidence that high ambient temperature depresses thyroid function and indicates that turnover rate one-half time may be used with a relatively high degree of accuracy in predicting thyroid activity in ewes.

The advantages of conducting an output turnover rate one-half time study to predict thyroid activity over the 1-thyroxine secretion rate method are:

a. Smaller dosage of I^{131} required.

b. Conducted in a shorter period of time.

c. Fewer I^{131} counts necessary.

d. Daily injections are not required.

The chief disadvantage is that turnover rate gives only a comparative estimate of thyroid activity; whereas, l-thyroxine secretion rate gives an absolute estimate.

D. Effect of Ambient Temperature and Artificial Light on Weight and Iodine Content of Thyroid Gland:

Immediately following slaughter of the native fine wool ewe on each of the experiments, the thyroid gland was dissected free of adhering tissue, weighed on an analytical balance, and one lobe was frozen for later iodine determination.

The native ewes which were to be slaughtered for the 8 hours of light, 55° F. and 8 hours of light, 85° F. groups were accidentally bred and were not slaughtered; therefore, no data are available for these groups.

Iodine content of the thyroid gland was determined by the method of Reineke et. al. (1945) and the results are shown in table 9. In all cases the percent iodine of the wet thyroid weight was based on the analysis of one lobe of the gland.

Due to the small number of animals for each temperature and light condition, no significant difference was found among any of the groups with respect to weight of the thyroid gland or iodine content expressed as a percent of wet thyroid weight.

Only slight differences existed in percent iodine content for any of the temperature and light conditions studied with a low value of 0.132 and a high value of 0.156 percent.

The author is unable to explain the extremely high value of 2.033 percent iodine obtained on the ewe reported separately. All computations and analytical procedures were double checked; however, there is a possibility that the glassware may have been contaminated and the value may not be real.

Table 9

Effect of Ambient Temperature and Artificial Light on Weight and Iodine Content of Thyroid Gland

Condition	No. Animals	Average Wt. of Animals (lbs.)	Average Wt. of Thyroid (grams)	Mg. Thyroid per lb. Body Weight	Average Iodine Content (mg.)	Micrograms Iodine per lb. Body Weight	Percent Iodine of Thyroid Weight
50° F.	3	90	2.5717	28.57	3.46	38	0.134
55° F.	2	88	1.8107	18.57	2.81	30	0.156
85° F.	1	93	2.1707	23.34	3.17	34	0.146
90° F.	3	114	2.0790	18.24	3.10	27	0.149
8 hours light	2	106	2.2967	20.82	2.87	27	0.132
12 hours light	4	94	2.0814	22.08	3.19	34	0.154
16 hours light	3	104	2.3417	22.52	3.34	32	0.142

Note: Since one of the ewes at 16 hours of light and 85° F. showed an extremely high value for iodine content, it is listed separately below.

	1	79	2.3410	29.63	47.59	602	2.033

E. Effect of Ambient Temperature and Artificial Light on Thyroid Activity as Measured by Histological Examination:

As was the case for percent iodine determinations, ewes at 8 hours of light, 55° F. and 8 hours of light, 85° F. are not included in this phase of the study since they accidentally became pregnant and were not slaughtered.

All data are based on the examination of one lobe of the thyroid gland as the other lobe was used for iodine determinations.

Immediately after slaughter of each animal, the thyroid was dissected free of all adhering tissue, weighed, and fixed in 10 percent formalin. The tissue was embedded in paraffin, sectioned at 10 micra and stained with Harris haematoxylin-eosin.

The height of one epithelial cell was measured in each of 20 randomly selected follicles for each animal, using the technique of Rawson and Starr (1938). The height of cells was measured by an eye-piece micrometer mounted in a stage microscope and calibrated with a stage micrometer. All measurements were taken under oil immersion.

The results are shown in table 10. Analysis of variance revealed a significant difference ($P < .01$) among both temperature and light conditions. The cell height in the 50° F. group was significantly greater than either the 85° F. or 90° F. group; however, it was not different from the 55° F. group. Also the 55° F. group was significantly different from the 90° F. group but was not different from the 85° F. group.

Interpreting thyroid secretion rate to be in a linear relationship with epithelial cell height (Rawson and Starr, 1938), the temperature effects are very closely associated with the values recorded for I^{131} output turnover rate and 1-thyroxine secretion rate.

Table 10

Effect of Ambient Temperature and Artificial Light on Epithelial Cell Height of Thyroid Gland

Condition	No. Animals	Average Height of Epithelial Cells (Micra)
50° F.	3	10.79**
55° F.	2	9.04*
85° F.	2	7.79
90° F.	3	6.39
8 hours light	2	8.73
12 hours light	4	7.66
16 hours light	4	9.32*

*Significantly different from the least value
**Significantly different from the two least values

These data are further evidence that ambient temperature has a profound effect upon thyroid activity in ewes.

Although analysis of variance revealed a highly significant difference among light conditions ($P<.01$), the author tends to discount some of the difference since only the 50° and 90° F. animals are included in the 8 hour group; whereas, ewes from all experimental temperatures are included in the 12 and 16 hour groups.

These data indicate greater thyroid activity at 16 hours of light than 12 hours which is in contradiction with the I^{131} output turnover values. Again the author cautions that the turnover rate studies are based on 72 animals; whereas, the histological studies are based on 10 animals, and furthermore, these data are non-orthogonal.

F. Effect of Ambient Temperature and Artificial Light on Body Weight Gains:

All ewes were weighed at the beginning of the experimental period and again at the end and total gain for the 20 day period recorded. Feed, water and trace mineral salt were fed *ad. lib.* prior to being placed on experiment and during the experimental period. The results are shown in table 11. The ewes increased in size from the beginning of the series of experiments from an average of 80 pounds to an average of 140 pounds at the end. Recognizing the fact that weight gains tend to decrease as an animal becomes older and fatter, time of experiment was treated as a replication and the variation due to this source was removed from the data by analysis of variance.

Table 11

Daily Body Weight Gains of Ewes Fed *ad. lib.* Under Controlled Ambient Temperature and Artificial Light Conditions[1]

Hours of Artificial Light	Ambient Temperature				
	50° F.	55° F.	85° F.	90° F.	Average
8	.364	.478	.236	.243	.331
12	.250	.350	.428	.086	.279
16	.280	.300	.307	.265	.313
Average	.331*	.376*	.324*	.198	.307

[1]The value reported for each temperature and light condition is an average of seven ewes.
*Significantly different from the least value

Weight gains at 90° F. were significantly lower ($P<.05$) than at 50° F., 55° F., or 85° F. There was no significant difference between gains at 50° F., 55° F., or 85° F.

Although weight gains at 12 hours of artificial light were slightly lower than 8 hours or 16 hours, there was no significant difference between any of the values nor was there a significant interaction between ambient temperature and artificial light.

These data are in agreement with the conclusions of Ragsdale <u>et. al.</u> (1949), (1951), and (1953) who concluded that high ambient temperatures severely depress or retard body weight gains in dairy cattle and Heitman <u>et. al.</u> (1951) who reported that pregnant sows lose weight at high ambient temperatures.

A significant correlation of -.23 ($P<.05$) was obtained when weight gains were correlated with ambient temperature; however, the relationship appears to be non-linear.

A correlation of -.23, which approaches significance, ($P<.10$) was obtained when weight gains were correlated with turnover rate one-half time. Although the correlation value is not significant, it indicates that weight gains are associated with thyroid function as reported by Scow and Marx (1945), Reineke <u>et. al.</u> (1948), Beeson <u>et. al.</u> (1947), and many others.

From these data, it may be concluded that ambient temperature does effect body weight gains which are greatly retarded at 90° F. and that artificial light has little or no effect.

G. Effects of Ambient Temperature and Artificial Light on Feed Consumption:

Since the experimental animals almost doubled in weight from the beginning of the experimental period to the end and because maintenance requirements increase with weight by a power of .73 (Brody, 1945) it was necessary to adjust all feed consumption data to an equal metabolic weight basis before the analysis was conducted. The results of the adjusted feed consumption data during the 20 day experimental period are shown in table 12. Ewes at 55° F. consumed a significantly greater

Table 12

Daily Feed Consumption Per Pound of Body Weight of Ewes Fed ad. lib. Under Controlled Ambient Temperature and Artificial Light Conditions[1]

Hours of Artificial Light	Ambient Temperature				
	50° F.	55° F.	85° F.	90° F.	Average
8	.034	.055	.043	.041	.043*
12	.034	.045	.039	.037	.039
16	.040	.052	.041	.040	.043*
Average	.036	.051***	.041	.039	.042

[1]The value reported for each temperature and light condition is an average of seven ewes.
*Significantly different from the least value
***Significantly different from the three least values

amount of feed ($P < .01$) than ewes at 50°F., 85° F., or 90° F.; however, there was no significant difference between the 50° F., 85° F., and 90° F. groups. Both the 50° and 90° F. groups were in the last series of experiments conducted and the ewes were in a high state of condition when they went on experiment. This may account for the small amount of feed consumed; whereas, the 55° and 85° F. groups were in the first series of experiments conducted and the animals were in a medium state of condition at that time.

The pooled value of .043 pounds of feed consumed per pound of body weight for the 50° and 55° F. groups is significantly different ($P<.05$) from the pooled value of .040 for the 85° and 90° F. groups. This is a logical and perhaps the most valid comparison of temperature effects on feed consumption since each of the pooled groups is made up of ewes in a high and medium degree of fatness at the beginning of the respective experiments.

From these data, one can conclude that high ambient temperatures greatly depress feed consumption in ewes. This is in agreement with the results of Reik et. al. (1950), Maqsood and Reineke (1950), and Robinson and Lee (1947) who reported that high ambient temperatures depressed feed consumption in sheep, rats, and other animals.

Twelve hours of artificial light resulted in a significantly lower ($P<.05$) feed intake than did either 8 or 16 hours. Although the 12 hour group showed the greatest thyroid activity, it remained the lowest group with respect to feed consumption and body weight gains.

On the basis of these data and the published literature pertaining to the effects of light on feed consumption in poultry and swine, the author is unable to explain the results and a more extensive study is needed before final conclusions can be drawn.

H. Effect of Ambient Temperature and Artificial Light on Water Consumption:

All experimental groups of ewes were given water *ad. lib.* during the seven day acclimatization period and during the 20 day experimental period with exception of the 50° F. group. The 50° F. group was offered all the water they would consume during a one-hour period of time twice daily. This procedure was followed in an attempt to reduce humidity in the 50° F. chamber to that previously recorded in the 55° F. chamber. During the pre-experimental period, water consumption by the two methods was compared with no differences evident.

No corrections were made for evaporation losses since the loss was slight at all temperatures. Fresh water was supplied daily in an amount slightly in excess of daily consumption. The results are shown in table 13.

Table 13

Pounds of Water Consumed Daily by Ewes Under Controlled Ambient Temperature and Artificial Light Conditions[1]

Hours of Artificial Light	Ambient Temperature				
	50° F.	55° F.	85° F.	90° F.	Average
8	5.00	9.42	9.06	9.49	8.24
12	4.81	9.38	9.04	10.66	8.47
16	6.67	9.80	9.15	8.52	8.54
Average	5.49	9.54*	9.09*	9.55*	8.42

[1]The value reported for each temperature and light condition is an average of seven ewes.
*Significantly different from the least value

Although analysis of variance shows a significant difference ($P < .01$) between water consumption at 50° F. over all other temperatures, the author is of the opinion that a part of it should be discounted since the 50° F. group did not have water before them at all times and a part of the low value shown for the 50° F. group may be due to this factor.

There was no significant difference between the 55° F., 85° F., and 90° F. groups and no significant difference shown among the light groups. A significant correlation (.44 $P < .01$) was again shown between ambient temperature and water consumption as was the case when ambient temperature was correlated with body weight gains or feed consumption. Again, the author cautions that the greatest part of the correlation is due to the low value obtained for the 50° F. group.

A great deal of individual variation existed among animals (Appendix P) at each of the temperature and light conditions studied and as reported by Ragsdale et. al. (1949), water consumption tends to parallel feed consumption except at high temperatures where it tends to increase with temperature.

Artificial light within the range studied appears to have no effect on water consumption.

I. Effects of Ambient Temperature and Artificial Light on Rectal Body Temperature:

Temperatures were taken every other day throughout the 20 day experimental period by the use of rectal thermometers and the results are shown in table 14.

Table 14

Effect of Controlled Ambient Temperature and Artificial Light Conditions on Rectal Body Temperatures in Ewes[1]

Hours of Artificial Light	Ambient Temperature				
	50° F.	55° F.	85° F.	90° F.	Average
8	102.7	103.5	104.1	102.8	103.3
12	102.4	102.8	103.5	103.7	103.1
16	102.2	103.1	103.7	103.2	103.1
Average	102.5	103.1*	103.8***	103.2*	103.1

[1]The value reported for each temperature and light condition is an average of seven ewes.
*Significantly different from the least value
***Significantly different from the three least values

Analysis of variance revealed a significant difference ($P<.01$) among temperatures with the 50° F. group being significantly lower than all others and the 85° F. group being significantly higher than all other groups. A significant correlation of .50 ($P<.01$) was obtained when ambient temperature was correlated with rectal body temperature. This differs somewhat from the field studies in dairy bulls by Johnston and Branton (1952) which indicated significant correlations between body temperature and ambient temperature only when the ambient temperature was within 40° to 60° F. and 70° to 80° F. intervals. However, these data are in agreement with the work of Casady et. al. (1956) who found a high correlation between rectal temperature and ambient chamber temperature of young dairy bulls at temperatures ranging from 60° to 95° F.

A great deal of variation existed among ewes at all temperatures studied which indicates that certain ewes have an inherant ability to maintain relatively low rectal temperatures at high environmental temperatures. This indicates that the animal breeder may have an opportunity to select for heat tolerance in the breeding program and eventually build up some natural resistance to high ambient temperature.

The author is unable to explain the low value obtained for the 90° F. group since respiration rate as shown in table 15 was also lower than that shown by the 85° F. group except that perhaps the physiological heat dissipation mechanisms were functioning more effectively at the 90° F. temperature.

There was little or no difference in rectal temperature at the various artificial light conditions; however, a significant interaction ($P<.01$) was found between ambient temperature and artificial light with the lowest rectal temperature at 50° F. and 16 hours of light and the highest at 85° F. and 8 hours of light.

Thyroid activity as measured by turnover rate of I^{131} has a positive association with rectal body temperature; however, the correlation coefficient of .15 was not significant ($P<.10$). Since a significant correlation of .28 ($P<.05$) was obtained between turnover rate of I^{131}

and ambient temperature, it indicates that thyroid function is affected more by the environmental temperature to which the animal is subjected than by rectal body temperature.

J. Effects of Ambient Temperature and Artificial Light on Respiration Rate:

Due to the extreme variation in respiration rate from day to day and between different periods of time during a given day for a given ewe, data were collected daily throughout the 20 day experimental period by counting flank movements. The daily values were averaged and the results are shown in table 15.

Table 15

Effects of Ambient Temperature and Artificial Light Conditions on Respiration Rate in Ewes[1]

(Flank movements per minute)

Hours of Artificial Light	Ambient Temperature				
	50° F.	55° F.	85° F.	90° F.	Average
8	39	85	148	113	96.5
12	51	49	126	139	91.4
16	41	105	155	139	109.6**
Average	43.6	80.0*	143.0**	130.3**	99.2

[1]The value reported for both temperature and light condition is an average of seven ewes.
*Significantly different from the least value
**Significantly different from the two least values

Analysis of variance revealed a significant difference ($P < .01$) among temperatures and again, as was the case with rectal temperature, respiration rate increased with increasing temperature with the exception of the 90° F. group which revealed a lower respiration rate than the 85° F. group. A correlation coefficient of .81 between ambient temperature and respiration rate was highly significant ($P < .01$) and was of the greatest magnitude of any of the factors correlated with ambient temperature.

These data essentially agree with the findings of Casady _et. al._ (1956) who reported that at ambient temperatures of 90° to 95° F., a great deal of individual variation existed in respiration rate of young dairy bulls and at these temperatures, respiration rate was not closely associated with rectal temperature and could not be used as an indice of thermal stress. Also Johnston and Branton (1953) and Johnston _et. al._ (1954) showed that respiration rate was consistently related to environmental temperature. In addition, McDowell _et. al._ (1953) in chamber studies with bulls concluded that respiration rate was not significantly correlated with rectal temperature but was significantly correlated with chamber temperature.

Respiration rate at 16 hours of light was significantly different ($P < .01$) from both 8 and 12 hours of light with a significant interaction ($P < .01$) between temperature and light.

Apparently, 16 hours of artificial light represented a stressful condition, and to a lesser extent, 8 hours of artificial light. This was also borne out by many of the other physiological responses studied.

K. General Discussion of the Effect of Ambient Temperature and Artificial Light on Certain Physiological Responses:

A summary of the effects of controlled ambient temperature and artificial light on the various physiological responses studied are shown in table 16 and 17 respectively, with correlation coefficients shown in table 18. Also a summary of the correlation coefficients between turnover rate of I^{131} by the thyroid and certain physiological activities are shown in table 19.

Upon examination of these data, it is evident that zero time uptake is the only uptake value not confounded with output. This is confirmed by the fact that correlation values between uptake and turnover rate one-half time increased progressively in magnitude from zero time to ten days after injection of I^{131} as shown in table 19.

It seems clear that the differences in correlation are due to depletion of I^{131} from the thyroid and that uptake values at three, five and ten days after injection, as well as maximum uptake, are confounded with output rate.

Since all of the correlations are positive, this actually means that there is an inverse relationship between uptake and turnover rate one-half time because a long turnover rate value indicates a slow output rate.

Also upon examination of figure 2 and the uptake values shown in table 16, it seems clear that a different relationship exists for the 90° F. group which is above the critical temperature for sheep, and

Table 16

Summary of Certain Physiological Responses to Controlled Ambient Temperature in Ewes

Responses Studied	Ambient Temperature			
	50° F.	55° F.	85° F.	90° F.
Zero time percent uptake of I^{131} [1]	15.29	14.69	15.67	13.07
One day percent uptake of I^{131} [1]	7.01	9.02**	8.61*	5.74
Three day percent uptake of I^{131} [1]	11.20	11.13	11.48	10.44
Maximum percent uptake of I^{131} [1]	11.92	11.95	13.28	11.19
Day of maximum percent uptake of I^{131} [1]	3.67	3.61	3.78	3.39
Turnover rate one-half time of I^{131} (days) [1]	12.50	13.08	14.71	17.74*
Daily body weight gains [2]	.33*	.38*	.32*	.20
Daily feed intake per pound of body weight (pounds) [2]	.04	.05***	.04	.04
Daily water intake (pounds) [2]	5.49	9.54*	9.09*	9.55*
Rectal body temperature [2]	102.5	103.1*	103.8***	103.2*
Respiration rate (flank movements per minute) [2]	47	80*	143**	130**

[1] The value reported for each temperature is an average of eighteen ewes.
[2] The value reported for each temperature is an average of twenty-one ewes.
*Significantly different from the least value
**Significantly different from the two least values
***Significantly different from the three least values

Table 17

Summary of Certain Physiological Responses to Controlled Artificial Light in Ewes

Responses Studied	Hours of Artificial Light		
	8	12	16
Zero time percent uptake of I^{131} [1]	15.23*	11.92	16.87*
One day percent uptake of I^{131} [1]	8.63*	6.43	7.73
Three day percent uptake of I^{131} [1]	11.21	9.55	12.44*
Maximum percent uptake of I^{131} [1]	12.48*	9.90	13.78*
Day of maximum percent uptake of I^{131} [1]	15.23*	11.92	16.87*
Turnover rate one-half time of I^{131} [1]	13.80*	12.57	15.73*
Daily body weight gains (pounds) [2]	.33	.28	.31
Daily feed intake per pound of body weight (pounds) [2]	.043*	.038	.043*
Daily water intake (pounds) [2]	8.24	8.47	8.54
Rectal body temperature [2]	103.3	103.1	103.1
Respiration rate (flank movements per minute) [2]	97	91	110*

[1] The value reported for each light condition is an average of twenty-four ewes.

[2] The value reported for each light condition is an average of twenty-eight ewes.

*Significantly greater than the least value

Table 18

Correlation Between Controlled Ambient Temperature and Certain Physiological Responses in Ewes

Correlation Between Ambient Temperature and:	df	r	Level of Significance
Turnover rate of I^{131} one-half time	72	.28	.05
Secretion rate of l-Thyroxine	12	-.60	.05
Body weight gains	84	-.23	.05
Feed Consumption	84	-.76	.01
Water Consumption	84	.44	.01
Rectal Temperature	84	.50	.01
Respiration Rate	84	.81	.01

Table 19

Correlation Between Turnover Rate One-Half Time and Certain Physiological Responses in Ewes

Correlation Between Turnover Rate One-Half Time and:	Including 90° F. Group			Excluding 90° F. Group		
	df	r	p	df	r	p
Zero time percent uptake of I^{131}	72	-.01				
One day percent uptake of I^{131}	72	.10				
Three day percent uptake of I^{131}	72	.29	.05	54	.38	.01
Five day percent uptake of I^{131}[1]				54	.42	.01
Ten day percent uptake of I^{131}[1]				54	.66	.01
Maximum percent uptake of I^{131}	72	.41	.05	54	.60	.01
l-Thyroxine secretion rate	12	-.27	.10			

[1] Values are expressed as percent uptake of I^{131}; however, they actually represent the percent of injected I^{131} contained in the thyroid on the day in question.

the effects of ambient temperature on uptake are not direct and simple. This is borne out by the fact that turnover rate one-half time was slower as temperatures increased; whereas, uptake increased with increasing temperature until temperature reached 90° F. At this point, uptake was considerably depressed and resulted in the lowest uptake values of any temperature studied. By eliminating the 90° F. group, the correlation values between uptake and turnover rate, as shown in table 19, were greatly increased and became more highly significant.

In view of these data, zero time uptake represents the only true uptake value not confounded with output rate and since it is not correlated with output rate, one can only conclude that it is of no value in predicting thyroid activity in ewes. Further evidence of this is shown by the fact that very little difference was observed in I^{127} content of the thyroid gland (table 9) at any of the temperatures studied; whereas, significant differences existed among temperatures for turnover rate, l-thyroxine secretion rate and thyroid epithelial cell height (tables 6, 8 and 10).

Daily hours of artificial light which the ewes were exposed to had a significant effect on both uptake and turnover rate of I^{131} as shown in figure 3 and table 17. The inverse relationship between uptake and turnover rate was of about the same magnitude at all light conditions studied; therefore, the relationship between uptake and artificial light appears to be less complicated than was the case with temperature.

From these data, it is evident that below the critical temperature and within a light range of 8 and 16 hours daily, three day, five day, ten day, and maximum uptake values of I^{131} can be used to predict thyroid activity in ewes; a low value indicating a more active gland than a high value.

Both rectal body temperature and body weight gains in ewes are shown to be significantly correlated with thyroid activity (table 19); however, a higher correlation was obtained between ambient temperature and these factors (table 18). This would indicate that all of the effects of temperature are not exerted through the thyroid.

High ambient temperature was found to have a significant depressing effect on body weight gains and feed intake, and significantly increased water intake, rectal body temperature and respiration rate (table 16).

Daily hours of artificial light which the ewes were exposed to appeared to have little effect upon body weight gains, water intake and body temperature; but did have a significant effect upon feed intake and respiration rate (table 17). Since the ewes responded to 12 hours of light more favorably than to 8 or 16 hours for all conditions studied with the exception of body weight gains and feed consumption, it is clear that 12 hours of artificial light represents less stress than either 8 or 16 hours. No significant correlation existed between hours of artificial light and any of the factors studied.

VI. SUMMARY AND CONCLUSIONS

The effect of ambient temperature and artificial light on thyroid activity and other metabolic measures in ewes is reported.

A total of 12 experiments involving 7 ewes each was conducted in controlled temperature and light chambers. Each experiment was conducted over a period of 27 days with 7 days devoted to acclimatization and 20 days to collection of data. All experimental animals were maintained in a similar environment prior to being placed on experiment.

Estimates of thyroid activity were obtained by the following methods:

Thyroidal Uptake of I^{131}

Thyroidal Output-Turnover Rate of I^{131}

1-Thyroxine Secretion Rate

Chemical Determination of Thyroidal I^{127}

Histological Determination of Thyroid Epithelial Cell Height

Estimates of thyroid activity obtained by all five methods were in very close agreement with the exception of thyroidal content of I^{127} and percent uptake of I^{131} which failed to reveal any significant difference among the various temperature studies.

It was demonstrated that ambient temperature had a profound effect on thyroid activity, with high temperature greatly suppressing and low temperature stimulating thyroid activity. The relationship between ambient temperature and thyroid activity as measured by turnover rate one-half time was significantly correlated ($P < .05$) and it appeared to be curvilinear.

Correlation analysis showed a significant ($P < .01$) inverse relationship between three day, five day, ten day, and maximum percent uptake of I^{131} and thyroid activity as measured by turnover rate one-half time of I^{131} which demonstrates that an actively secreting thyroid was accompanied by a low uptake of I^{131} and vice versa. Uptake values taken between three and ten days after injection of I^{131} appear to be a reliable estimate of thyroid activity in ewes at temperatures below 90° F.

Ewes subjected to 12 hours of artificial light daily showed significantly greater values for thyroid activity than did ewes at 8 or 16 hours of light as measured by turnover rate one-half time of I^{131}.

Daily body weight gains, daily feed intake per pound of body weight, daily water intake, rectal body temperature, and respiration rate were all found to be significantly affected by ambient temperature. Significant correlations were obtained between ambient temperature and respiration rate (0.81), feed consumption (-0.76), rectal body temperature (0.50), and water consumption (0.44).

Daily hours of artificial light had a significant effect on feed consumption and respiration rate, but had little or no effect on rectal body temperature, water intake, and body weight gains.

Based on the results and discussion presented, the following general conclusions may be drawn:

1. High ambient temperatures significantly depress thyroid activity in ewes; whereas, low ambient temperatures stimulate thyroid activity as measured by turnover rate of I^{131}, l-thyroxine secretion rate, and thyroid epithelial cell height.
2. Ambient temperature within the range of 50° to 90° F. has no significant effect on zero time uptake of I^{131} or thyroid content of I^{127} in ewes.
3. Thyroid activity is significantly greater in ewes maintained under 12 hours of artificial light daily than in ewes maintained under 8 or 16 hours of light as measured by turnover rate one-half time of I^{131}.
4. Thyroid content of I^{127} in ewes is not significantly affected by exposure to artificial light within the range of 8 to 16 hours daily.
5. Output-turnover rate of I^{131} is a reliable estimate of thyroid activity in ewes under controlled environment.
6. Three day, five day, ten day, and maximum percent uptake of I^{131} in ewes under controlled environment and below 90° F. is inversely related to thyroid activity.
7. Three day, five day, ten day, and maximum percent uptake of I^{131} can be of value in predicting thyroid activity in ewes under controlled environment and below 90° F.
8. Daily body weight gains, daily feed intake per pound of body weight, daily water intake, rectal body temperature, and respir-

ation rate in ewes are all significantly affected by and correlated with ambient temperature.

9. Daily feed intake per pound of body weight and respiration rate in ewes are significantly affected by artificial light; however, artificial light has no significant effect on daily body weight gains, daily water intake and rectal body temperature.

VII. BIBLIOGRAPHY

Beakley, W. R. and J. D. Findlay. 1955a. The effect of environmental temperature and humidity on the skin temperature of Ayrshire calves. J. Agri. Sci. 45:353.

Beakley, W. R. and J. D. Findlay. 1955b. The effect of environmental temperature and humidity on the respiration rate of Ayrshire calves. J. Agri. Sci. 45:452.

Beeson, W. M., F. N. Andrews, H. L. Witz and T. W. Perry. 1947. The effect of thyroprotein and thiouracil on the growth and fattening of swine. J. Animal Sci. 6:482.

Berliner, V. and V. Warbritton. 1937. The pituitary and thyroid in relation to sperm production in rams. Amer. Soc. An. Prod. Proc. pp. 137-142.

Bissonnette, T. H. 1932. Modification of mammaliam sexual cycles. Proc. Royal Soc. B. 11:322.

Black, W. G., A. L. Schick, A. L. Pope and L. E. Cassida. 1950. Some effects of testosterone propionate and thyroprotein in rams. J. Animal Sci. 9:186.

Bogart, R. and D. T. Mayer. 1946. Environmental temperature and thyroid gland involvement in lowered fertility of rams. Missouri Agri. Expt. Sta. Res. Bul. 402.

Brody, Samuel. 1945. Bioenergenetics and Growth. Reinhold Publishing Co., New York.

Casady, R. B. 1953. The effect of exposure to high ambient temperature on spermatogenesis in the dairy bull. J. Dair Sci. 36:14.

Casady, R. B., J. E. Legates and R. M. Myers. 1956. Correlations between ambient temperature varying from 60° to 95° F. and certain physiological responses in young dairy bulls. J. Animal Sci. 15:141.

Chai, C. K., A. Amin, and E. P. Reineke. 1957. Thyroid iodine metabolism in inbred and f_1 hybrid mice. Am. Jour. Physiol. 188:499.

Cramer, W. 1916. On the thyroid - adrenal apparatus and its function in heat regulation of the body. J. Physiol. 50:38.

Dempsey, E. W. and E. B. Astwood. 1943. Determination of the thyroid hormone secretion at various environmental temperatures. Endocrin. 32:509.

Dutt, R. H. and L. F. Bush. 1955. The effect of low environmental temperature on initiation of the breeding season and fertility in sheep. J. Animal Sci. 14:885.

Dutt. R. H., E. F. Ellington and W. W. Carlton. 1956. Effect of shearing and exposure to elevated air timperature on fertility and early embryo survival in ewes. J. Animal Sci. 15:1287.

Flamboe, Eugene A. 1958. A study of thyroid activity in dairy goats relating to age, lactation, pregnancy and season of the year. Ph.D. Thesis, Michigan State University.

Fletcher, J. L. and G. R. Reid. 1953. The effect of shearing on the reaction of lambs to high environmental temperatures. J. Animal Sci. 12.666.

Foote, W. C., A. L. Pope, R. E. Nichols, and L. E. Casida. 1957. The effect of variation in ambient temperature and humidity on rectal and testes temperature of shorn and unshorn rams. J. Animal Sci. 16:144.

Freinkel, N. and D. Lewis. 1957. The effect of lowered environmental temperature on the peripheral metabolism of labelled thyroxine in sheep. J. Physiol. 135:288.

Green, W. W. 1940. Seasonal trends of sperm cell types in sheep. Am. Soc. of An. Prod. Proc. pp 307-315.

Hafez, E. S. E. 1950. Sexual season of the ewe and daylight environment. Nature 166:822.

Hafez, E. S. E. 1951. Inhibility action of artificial light on the sexual season of the ewe. Nature 168:336.

Hafez, E. S. E. 1952. Studies on the breeding season and reproduction of the ewe. J. Agri. Sci. 42:189.

Hammond, J. Jr., 1944. On the breeding season in sheep. J. Agri. Sci. 34:97.

Hart, D. S. 1950. Photoperiodicity in Suffolk sheep. J. Agri. Sci. 40:143.

Hart, D. S. 1950. Photoperiodicity in the female ferret. J. Expt. Biology 28:1.

Henneman, H. A., E. P. Reineke and S. A. Griffin. 1955. The thyroid secretion rate of sheep as affected by season, age, breed, pregnancy, and lactation. J. Animal Sci. 14:419.

Heitman, H., E. H. Hughes and C. F. Kelly. 1951. Effect of elevated ambient temperature on pregnant sows. J. Animal Sci. 10:907.

Heitman, H. and E. H. Hughes. 1949. The effect of air temperature and relative humidity on the physiological well being of swine. J. Animal Sci. 8:171.

Hurst, V. and C. W. Turner. 1948. The thyroid secretion rate in the mouse and its relation to various physiological processes. Missouri Expt. Sta. Res. Bul. 417.

Jaap, R. G. 1933. Testes enlargement and thyroid administration in ducks. Poultry Sci. 12:322.

Johnston, J. E. and C. Branton. 1952. Relationship of maximum daily air temperature and humidity to physiological reactions of dairy bulls. J. Dairy Sci. 36:14.

Johnston, J. E. and C. Branton. 1953. Effects of seasonal climatic changes on certain physiological reactions, semen production and fertility of dairy bulls. J. Dairy Sci. 36:934.

Johnston, J. E., H. Kellgren, H. Kaclapaa, J. B. Frye, Jr., J. J. Vizinat and E. Green. 1954. Effects of elevated temperatures and humidities on physiological respons and semen production of Holstein, Brown Swiss, Jersey, and Red Sindhi crossbred bulls. (Unpublished). Reviewed in J. Animal Sci. 15:141.

Kendall, E. C. and D. G. Simonsen. 1928. Seasonal variation in the iodine and thyroxine content of the thyroid gland. J. Biol. Chem. 80:357.

Lee, D. H. 1945. Poultry Husbandry in hot climates - experimental inquiries. Poultry Sci. 24:195.

Lewis, R. C., E. P. Reineke and J. R. Lodge. 1955. A technique for estimating thyroid secretion rate in dairy cattle. (Abstract) J. Animal Sci. 14:1250.

Magnus-Levy, A. Berl. Klin. Wochsehr. 1895. 32:650. Cited by Reineke, E. P. and C. W. Turner. Chapt. XIII. Thyroidal substances. Emmens. C. W., Editor. Hormone Assay. Academic Press. New York. 1950.

Maqsood, M. and E. P. Reineke. 1950. Influence of variation in environmental temperature and thyroid status on growth and feed consumption of the male mouse. Amer. J. Physiol. 160:253.

Maqsood, M. 1950. The role of the thyroid in sexual development in the male. Nature 166:692.

Marshall, F. S. H. 1940. The experimental modification of the estrus cycle in the ferret by different intensities of light. J. Expt. Biol. 17:139.

Martinez Campos, C. M. S. 1947. The influence of varying levels of thyroid activity on semen production in the domestic fowl. M.S. Thesis, Michigan State University.

Masson, G. 1947. Action de la thyroxine sur l'effect testoide de la testosterone. Revue Canadiene Biologil 6:355.

Meites, J. and B. Chandrashaker. 1948. Effect of thyroid status on the response of the gonads to pregnant mare's serum. J. Animal Sci. 7:542.

Mørch, J. R. 1929. Standardization of thyroid preparations. J. Physiol. 67:221.

McDowell, R. E., D. H. Lee, M. H. Fohrman and R. S. Anderson. 1953. Respiratory activity as an index of heat tolerance in Jersey and Sindhi x Jersey (F_1) crossbred cows. J. Animal Sci. 12:573.

McKenzie, F. F. and R. W. Phillips. 1933. The effects of temperature and diet on the onset of the breeding season (estrus) in sheep. Missouri Agr. Expt. Sta. Res. Bul. 328.

Mercier, E. and G. W. Salisbury. 1947a. Fertility level in artificial breeding associated with season, hours of daylight, and the age of cattle. J. Dairy Sci. 30:817.

Mercier, E. and G. W. Salisbury. 1947b. Seasonal variation in hours of daylight associated with fertility level of cattle under natural breeding conditions. J. Dairy Sci. 30:747.

Miller, J. C. and L. Monge. 1946. Body temperature and respiration rate and their relation to adaptability in sheep. J. Animal Sci. 5:147.

Mills, C. A. 1918. Effects of external temperature, morphine, quinine and strychnine on thyroid activity. Amer. J. Physiol. 46:329.

Mixner, J.P., E. P. Reineke and C. W. Turner. 1944. Effect of thiouracil and thiourea on the thyroid gland of the chick. Endocrin. 34:168.

Oloufa, M. M. 1951. Effect of environmental temperature and the thyroid gland on fertility in the male rabbit. Oregon State College Tech. Bul. 20.

Organon, R. F. 1936. The thyroid in relation to reproductive function. Hormones 2:49.

Perry, W. F. 1951. A method for measuring thyroid hormone secretion rate in the rat with its application to the bioassay of thyroid extracts. Endocrin. 48:643.

Petersen, W. E., A. Spillman, B. S. Pomeroy and W. L. Boyd. 1941. Effect of thyroidectomy upon sexual behavior of the male bovine. Proc. of Expt. Biol. and Med. 46:16.

Premachandra, B. N., G. W. Pipes and C. W. Turner. 1957. A study of thyroxine secretion rate in cattle. J. Animal Sci. 16:1063.

Puntriano, G. and Joseph Meites. 1951. The effect of continuous light or darkness on thyroid function in mice. Endocrin. 48:217.

Ragsdale, A. C., D. M. Worstell, H. J. Thompson and Samuel Brody. 1949. Environmental Physiology. VI. Influence of temperature, 50° to 0° F. and 50° to 95° F., on milk production, feed and water consumption and body weight in Jersey and Holstein cows. Missouri Agri. Expt. Sta. Res. Bul. 449.

Ragsdale, A. C., H. J. Thompson, D. M. Worstell and Samuel Brody. 1951. Environmental Physiology. XII. Influence of increasing temperature, 40° to 105° F. on milk production in Brown Swiss cows, and on feed and water consumption and body weight in Brown Swiss and Brahman cows and heifers. Missouri Agri. Expt. Sta. Res. Bul. 471.

Ragsdale, A. C., H. J. Thompson, D. M. Worstell, and Samuel Brody. 1953. Environmental Physiology and Shelter Engineering. XXI. The effect of humidity on milk production and composition, feed and water consumption and body weight in cattle. Missouri Agri. Expt. Sta. Res. Bul. 521.

Rawson, R. W. and P. Starr. 1938. Direct measurement of height of thyroid epithelium; a method of assay of thyrotrophic substances. Chem. Application Archives of Med. 61(5):726.

Reineke, E. P., A. J. Bergman and C. W. Turner. 1941. Effect of thyroidectomy of young male goats upon certain AP hormones. Endocrin. 29:306.

Reineke, E. P., C. W. Turner, G. O. Kohler, R. D. Hoover and M. B. Beezley. 1945. The determination of thyroxine in iodinated protein having thyroidal activity. J. Biol. Chem. 161:599.

Reineke, E. P. and C. W. Turner. 1945. Seasonal rhythm in the thyroid hormone secretion of the chick. Poultry Sci. 24:499.

Reineke, E. P., W. N. McMillen and L. J. Bratzler. 1948. The effect of mild thyroprotein stimulation on growth in swine. Michigan Agri. Expt. Sta. Tech. Bul. 209.

Reineke, E. P. and F. A. Soliman. 1953. Role of thyroid hormone in reproductive physiology of the female. Iowa State College J. of Sci. 28:67.

Reineke, E. P. and O. N. Singh. 1955. Estimation of thyroid secretion rate of the intact rat. Proc. Soc. for Expt. Biol. and Med. 88:203.

Reineke, E. P. and C. K. Chai, and A. Amin. 1956. The thyroidal iodine uptake and output rates in inbred mice. Amer. J. of Physiol. 187

Reik, R. F., M. H. Hardy, D. H. K. Lee and H. B. Carter. 1950. The effect of the dietary plane upon the reaction of two breeds of sheep during short exposures to hot environment. Aust. J. of Agri. Res. 1:217.

Robinson, K. and D. H. K. Lee. 1947. Effect of the nutritional plane upon the reactions of animals to heat. J. Animal Sci. 6:182.

Scow, R. O. and W. Marx. 1945. Response to pituitary growth hormone of rats thyroidectomized on day of birth. Anat. Rec. 91:227.

Seidell, A. and F. Fenger. 1912. Seasonal variation in the iodine content of the thyroid gland. J. Biol. Chem. 13:517.

Smelser, George K. 1939. Testicular function and the action of gonadotrophic and male hormones in hyperthyroid male rats. Anat. Rec. 73:273.

Snedecor, G. E. 1950. Statistical Methods. Iowa State College Press, Ames, Iowa.

Sykes, J. F. and C. L. Cole. 1944. Modification of mating season in sheep by light treatment. Mich. Agri. Expt. Sta. Quart. Bul. 26:4.

Teitelbaum, H. A. and O. G. Horne. 1941. A closed-circuit metabolism apparatus for studying oxygen consumption of control and thyroactivator treated guinea pigs. J. Lab. Clin. Med. 26:1521.

Terry, W. A. 1951. The effect of constant light or darkness on the thyroid gland of the sheep and on the estrous cycle. M. S. thesis, Michigan State University.

Turner, C. W. 1948. Effect of age and season on the thyroxine secretion rate of white leghorn hens. Poultry Sci. 27:146.

VanDyke, H. B. and G. Chen. 1933. Production of ovulation by anterior lobe of pituitary of thyroidectomized rabbit. Proc. Soc. Expt. Biol. and Med. 31:327.

Warwick, E. J., C. E. Childs, A. E. Flower and W. E. Ham. 1948. Ram semen production and characteristics as influenced by administration of thyroprotein. J. Animal Sci. 7:198.

Wheeler, R. S. and E. Hoffman. 1948. The value of thyroprotein in starting, growing, and laying rations. II. The growing period, 12-24 weeks of age. Poultry Sci. 27:509.

Yeates, N. T. M. 1949. The breeding season of the sheep with particular reference to its modifications by artificial means using light. J. Agri. Sci. 39:4.

Yeates, N. T. M. 1953. The effect of high air temperature on reproduction in the ewe. J. Agri. Sci. 43:199.

VIII. APPENDIX

Appendix A

Turnover Rate of I^{131} by the Thyroid in Ewes at 50^{o} F Controlled Ambient Temperature

Hours of Artificial Light	df	Sum of x	Sum of y	Sum of x^2-c.t.	Sum of y^2-c.t.	Sum of xy-c.t.	r	Level of Significance	b	Estimated Turnover Rate in Days
8	5	43	24.14547	23	.01590	- .59913	-.99	.01	-.02605	11.556
8	4	22	19.07372	5	.00381	- .13650	-.99	.01	-.02730	11.017
8	5	43	24.69568	23	.00931	- .43847	-.95	.01	-.01906	15.794
8	6	48	28.58411	34	.00759	- .47445	-.93	.01	-.01396	21.564
8	5	43	23.74627	23	.02830	- .77207	-.96	.01	-.03357	8.967
8	5	43	23.61794	23	.01689	- .60799	-.97	.01	-.02643	11.389
12	3	25	13.27777	19	.00371	- .22251	-.84	.07	-.01171	25.707
12	5	53	20.87614	59	.07240	-2.05094	-.99	.01	-.03476	8.661
12	4	48	16.71919	20	.00553	- .31597	-.95	.01	-.01580	19.053
12	5	53	20.59472	59	.03354	-1.30215	-.93	.01	-.02207	13.640
12	6	57	24.44217	96	.08083	-2.50841	-.90	.01	-.02613	11.520
12	3	39	13.50258	8	.00480	- .19598	-.99	.01	-.02450	12.287
16	5	50	20.07874	40	.04451	-1.29582	-.97	.01	-.03239	9.263
16	5	41	21.90643	33	.02214	- .83767	-.98	.01	-.02538	11.861
16	6	55	23.88612	61	.03696	-1.46336	-.97	.01	-.02399	12.538
16	6	55	24.16102	61	.01086	- .72881	-.90	.01	-.01195	25.191
16	6	55	24.07626	61	.04883	-1.50620	-.87	.01	-.02469	12.192
16	5	50	19.20789	40	.03226	-1.11948	-.99	.01	-.02799	10.755
Intra-Class Correlation	89	823	386.59222	688	.47817	-16.57591	-.91	.01	-.02409	12.496

Appendix B

Turnover Rate of I^{131} by the Thyroid in Ewes at 55° F Controlled Ambient Temperature

Hours of Artificial Light	df	Sum of x	Sum of y	Sum of x^2-c.t.	Sum of y^2-c.t.	Sum of xy-c.t.	r	Level of Significance	b	Estimated Turnover Rate in Days
8	5	50	18.26858	40.0	.04808	-1.22106	-.88	.01	-.03052	9.863
8	5	50	19.97586	40.0	.11896	-1.52012	-.70	.08	-.03800	10.472
8	5	50	17.69672	40.0	.03354	-1.09606	-.95	.01	-.02740	10.986
8	5	50	19.94417	40.0	.03087	-1.02086	-.92	.01	-.02552	15.594
8	5	50	20.18149	40.0	.00863	- .50974	-.86	.02	-.01274	31.236
8	5	50	20.35136	40.0	.01466	- .74646	-.99	.01	-.01866	21.326
12	5	45	19.32210	40.0	.02063	-1.45520	-.98	.01	-.03638	8.275
12	5	45	19.70226	40.0	.04461	-1.30984	-.98	.01	-.03274	9.194
12	5	45	19.50925	40.0	.03848	-1.21292	-.98	.01	-.30323	9.894
12	5	45	20.42923	40.0	.01419	- .66219	-.88	.01	-.01655	18.189
12	5	45	18.79004	40.0	.04442	-1.26694	-.95	.01	-.03167	9.505
12	5	45	19.17868	40.0	.02865	-1.05902	-.99	.01	-.02648	11.368
16	6	57	27.36041	83.5	.01163	- .70551	-.72	.04	-.00845	35.625
16	5	52	20.94570	59.2	.00918	- .73000	-.99	.01	-.01233	24.414
16	3	48	12.89466	32.0	.01361	- .63840	-.97	.01	-.01995	15.089
16	5	52	20.54842	59.2	.01413	- .87274	-.95	.01	-.01474	20.446
16	4	46	16.93986	35.0	.06060	-1.32197	-.91	.01	-.03777	7.970
16	4	46	17.60010	35.0	.01391	- .69749	-.99	.01	-.01993	15.105
Intra-Class Correlation	87	871	349.63889	783.9	.56878	-18.04652	-.85	.01	-.02302	13.077

Appendix C

Turnover Rate of I^{131} by the Thyroid in Ewes at 85° F Controlled Ambient Temperature

Hours of Artificial Light	df	Sum of x	Sum of y	Sum of x^2-c.t.	Sum of y^2-c.t.	Sum of xy-c.t.	r	Level of Significance	b	Estimated Turnover Rate in Days
8	5	50	19.65374	40.0	.02575	- .97112	-.96	.01	-.02428	16.389
8	5	50	19.77980	40.0	.02019	- .86526	-.97	.01	-.02163	18.398
8	5	50	20.60834	40.0	.01132	- .64636	-.97	.01	-.01616	18.629
8	5	50	19.46096	40.0	.03030	-1.03814	-.95	.01	-.02595	15.335
8	5	50	20.40169	40.0	.01224	- .73944	-.93	.01	-.01849	16.302
12	5	45	20.15674	40.0	.02456	- .96880	-.98	.01	-.02422	12.429
12	4	32	14.97989	20.0	.04258	- .90189	-.98	.01	-.04509	6.649
12	5	45	20.57201	40.0	.00420	- .35194	-.85	.02	-.00879	34.247
12	5	45	19.18003	40.0	.02087	- .84940	-.93	.01	-.02124	14.173
12	5	45	19.61809	40.0	.03176	-1.12038	-.99	.01	-.02801	10.747
12	5	45	19.16803	40.0	.04688	-1.27870	-.93	.01	-.03197	9.416
16	5	52	22.23227	59.2	.02834	-1.23728	-.96	.01	-.02090	14.403
16	4	46	17.66221	35.0	.01740	- .73269	-.94	.01	-.02093	14.383
16	5	52	22.13947	59.2	.00573	- .49330	-.84	.03	-.00833	36.138
16	5	52	21.78989	59.2	.05931	-1.70943	-.92	.01	-.02882	10.423
16	5	52	22.11509	59.2	.01478	- .86041	-.92	.01	-.01453	20.742
16	5	52	22.91204	59.2	.00884	- .60209	-.83	.04	-.01017	29.600
Intra-Class Correlation	83	813	342.43029	751.0	.41158	- 15.3663	-.87	.01	-.02046	14.713

Appendix D

Turnover Rate of I^{131} by the Thyroid in Ewes at 90° F Controlled Ambient Temperature

Hours of Artificial Light	df	Sum of x	Sum of y	Sum of x^2-c.t.	Sum of y^2-c.t.	Sum of xy-c.t.	r	Level of Significance	b	Estimated Turnover Rate in Days
8	5	45	24.48626	10	.00277	- .16171	-.97	.01	-.01617	18.614
8	7	54	33.95795	39	.00554	- .28709	-.62	.06	-.00736	40.901
8	6	50	25.81022	23	.01953	- .64067	-.95	.01	-.02786	10.807
8	6	50	27.31337	23	.01725	- .26900	-.43	.38	-.01170	25.729
8	6	50	26.87258	23	.00537	- .33508	-.96	.01	-.01457	20.661
8	5	45	21.38748	10	.00302	- .15993	-.92	.01	-.01599	18.827
12	5	53	18.96023	59	.03584	-1.20511	-.83	.03	-.02043	14.735
12	5	53	19.89616	59	.00692	- .60042	-.94	.01	-.01018	29.571
12	4	23	16.49301	39	.00761	- .38698	-.71	.09	-.00992	30.346
12	5	45	20.45917	40	.01068	- .63744	-.98	.01	-.01594	33.223
12	4	25	15.50449	23	.05230	-1.33117	-.83	.04	-.05788	5.200
12	4	29	16.53266	49	.00910	- .53261	-.80	.06	-.01087	27.695
16	5	50	20.70374	40	.03014	- .59138	-.54	.36	-.01478	20.367
16	5	50	21.42453	40	.00930	- .53908	-.89	.01	-.01348	22.331
16	6	55	25.01109	61	.00908	- .68232	-.92	.01	-.01119	26.901
16	5	50	20.56571	40	.05880	-1.45548	-.95	.01	-.03639	8.272
16	6	55	25.84697	61	.02086	-1.09866	-.98	.01	-.01801	16.715
16	5	50	21.10393	40	.04297	-1.29724	-.99	.01	-.03243	9.283
Intra-Class Correlation	94	832	402.32955	679	.33908	-12.21137	-.80	.01	-.01798	17.742

Appendix E

Turnover Rate of I^{131} by the Thyroid in Ewes at 8 Hours Controlled Artificial Light

Ambient Temperature	df	Sum of x	Sum of y	Sum of x^2-c.t.	Sum of y^2-c.t.	Sum of xy-c.t.	r	Level of Significance	b	Estimated Turnover Rate in Days
50° F	5	43	24.14547	23	.01590	- .59913	-.99	.01	-.02605	11.556
50° F	4	22	19.07372	5	.00381	- .13650	-.99	.01	-.02730	11.017
50° F	5	43	24.69568	23	.00931	- .43847	-.95	.01	-.01906	15.794
50° F	6	48	28.58411	34	.00759	- .47445	-.93	.01	-.01396	21.564
50° F	5	43	23.74627	23	.02830	- .77207	-.96	.01	-.03357	8.967
50° F	5	43	23.61794	23	.01689	- .60799	-.97	.01	-.02643	11.389
55° F	5	50	18.26858	40	.04808	-1.22106	-.88	.01	-.03052	9.863
55° F	5	50	19.97586	40	.11896	-1.52012	-.70	.08	-.03800	10.472
55° F	5	50	17.69672	40	.03354	-1.09606	-.95	.01	-.02740	10.986
55° F	5	50	19.94417	40	.03087	-1.02086	-.92	.01	-.02552	15.594
55° F	5	50	20.18149	40	.00863	- .50974	-.86	.02	-.01274	31.236
55° F	5	50	20.35136	40	.01466	- .74646	-.99	.01	-.01866	21.326
85° F	5	50	19.65374	40	.02575	- .97112	-.96	.01	-.02428	16.389
85° F	5	50	19.77980	40	.02019	- .86526	-.97	.01	-.02163	18.398
85° F	5	50	20.60834	40	.01132	- .64636	-.97	.01	-.01616	18.629
85° F	5	50	19.46096	40	.03030	-1.03814	-.95	.01	-.02595	15.335
85° F	5	50	20.40169	40	.01224	- .73944	-.93	.01	-.01849	16.302
90° F	5	45	24.48626	10	.00277	- .16171	-.97	.01	-.01617	18.614
90° F	7	54	33.95795	39	.00554	- .28709	-.62	.06	-.00736	40.901
90° F	6	50	25.81022	23	.01953	- .64067	-.95	.01	-.02786	10.805
90° F	6	50	27.31337	23	.01725	- .26900	-.43	.38	-.01170	25.729
90° F	6	50	26.87258	23	.00537	- .33508	-.96	.01	-.01457	20.661
90° F	5	45	21.38748	10	.00302	- .15993	-.92	.01	-.01599	18.827
Intra-Class Correlation	120	1086	520.01376	699	.47635	-15.25671	-.84	.01	-.02182	13.796

Appendix F

Turnover Rate of I^{131} by the Thyroid in Ewes at 12 Hours Controlled Artificial Light

Ambient Temperature	df	Sum of x	Sum of y	Sum of x^2-c.t.	Sum of y^2-c.t.	Sum of xy-c.t.	r	Level of Significance	b	Estimated Turnover Rate in Days
50° F	3	25	13.2777	19	.00371	- .22251	-.84	.07	-.01171	25.707
50° F	5	53	20.87614	59	.07240	-2.05094	-.99	.01	-.03476	8.661
50° F	4	48	16.71919	20	.00553	- .31597	-.95	.01	-.01580	19.053
50° F	5	53	20.59472	59	.03354	-1.30215	-.93	.01	-.02207	13.640
50° F	6	57	24.44217	96	.08083	-2.50841	-.90	.01	-.02613	11.520
50° F	3	39	13.50258	8	.00480	- .19598	-.99	.01	-.02450	12.287
55° F	5	45	19.32210	40	.02063	-1.45520	-.98	.01	-.03638	8.275
55° F	5	45	19.70226	40	.04461	-1.30984	-.98	.01	-.03274	9.194
55° F	5	45	19.50925	40	.03848	-1.21292	-.98	.01	-.30323	9.894
55° F	5	45	20.42923	40	.01419	- .66219	-.88	.01	-.01655	18.187
55° F	5	45	18.79004	40	.04442	-1.26694	-.95	.01	-.03167	9.505
55° F	5	45	19.17868	40	.02865	-1.05902	-.99	.01	-.02648	11.368
85° F	5	45	20.15674	40	.02456	- .96880	-.98	.01	-.02422	12.429
85° F	4	32	14.97989	20	.04258	- .90189	-.98	.01	-.04509	6.649
85° F	5	45	20.57201	40	.00420	- .35194	-.85	.02	-.00879	34.247
85° F	5	45	19.18003	40	.02087	- .84940	-.93	.01	-.02124	14.173
85° F	5	45	19.61809	40	.03176	-1.12038	-.99	.01	-.02801	10.747
85° F	5	45	19.16803	40	.04688	-1.27870	-.93	.01	-.03197	9.416
90° F	5	53	18.96023	59	.03584	-1.20511	-.83	.03	-.02043	14.735
90° F	5	53	19.89616	59	.00692	- .60042	-.94	.01	-.01018	29.571
90° F	4	23	16.49301	39	.00761	- .38698	-.71	.09	-.00992	30.346
90° F	5	45	20.45917	40	.01068	- .63744	-.98	.01	-.01594	33.223
90° F	4	25	15.50449	23	.05230	-1.33117	-.83	.04	-.05788	5.200
90° F	4	29	16.53266	49	.00910	- .53261	-.80	.06	-.01087	27.695
Intra-Class Correlation	112	1030	447.86464	990	.68509	-23.72619	-.91	.01	-.02396	12.564

Appendix G

Turnover Rate of I^{131} by the Thyroid in Ewes at 16 Hours Controlled Artificial Light

Ambient Temperature	df	Sum of x	Sum of y	Sum of x^2-c.t.	Sum of y^2-c.t.	Sum of xy-c.t.	r	Level of Significance	b	Estimated Turnover Rate in Days
50° F	5	50	20.07874	40.0	.04451	-1.29582	-.97	.01	-.03239	9.263
50° F	5	41	21.90643	33.0	.02214	- .83767	-.98	.01	-.02538	11.861
50° F	6	55	23.88612	61.0	.03696	-1.46336	-.97	.01	-.02399	12.548
50° F	6	55	24.16102	61.0	.01086	- .72881	-.90	.01	-.01195	25.191
50° F	6	55	24.07626	61.0	.04883	-1.50620	-.87	.01	-.02469	12.192
50° F	5	50	19.20789	40.0	.03226	-1.11948	-.99	.01	-.02799	10.755
55° F	6	57	27.36041	83.5	.01163	- .70551	-.72	.04	-.00845	35.625
55° F	5	52	20.94570	59.2	.00918	- .73000	-.99	.01	-.01233	24.414
55° F	3	48	12.89466	32.0	.01361	- .63840	-.97	.01	-.01995	15.089
55° F	5	52	20.54842	59.2	.01413	- .87274	-.95	.01	-.01474	20.446
55° F	4	46	16.93986	35.0	.06060	-1.32197	-.91	.01	-.03777	7.970
55° F	4	46	17.60010	35.0	.01391	- .69749	-.99	.01	-.01993	15.105
85° F	5	52	22.23227	59.2	.02834	-1.23728	-.96	.01	-.02090	14.403
85° F	4	46	17.66221	35.0	.01740	- .73269	-.94	.01	-.02093	14.383
85° F	5	52	22.13947	59.2	.00573	- .49330	-.84	.03	-.00833	36.138
85° F	5	52	21.78989	59.2	.05931	-1.70943	-.92	.01	-.02882	10.423
85° F	5	52	22.11509	59.2	.01478	- .86041	-.92	.01	-.01453	20.742
85° F	5	52	22.91204	59.2	.00884	- .60209	-.83	.04	-.01017	29.600
90° F	5	50	20.70374	40.0	.03014	- .59138	-.54	.36	-.01478	20.367
90° F	5	50	21.42453	40.0	.00930	- .53908	-.89	.01	-.01348	22.331
90° F	6	55	25.01109	61.0	.00908	- .68232	-.92	.01	-.01119	26.901
90° F	5	50	20.56571	40.0	.05880	-1.45548	-.95	.01	-.03639	8.272
90° F	6	55	25.84697	61.0	.02086	-1.09866	-.98	.01	-.01801	16.715
90° F	5	50	21.10393	40.0	.04297	-1.29724	-.99	.01	-.03243	9.283
Intra-Class Correlation	121	1223	515.11255	1213.0	.62417	-23.21682	-.84	.01	-.01914	15.728

Appendix H

Estimated Daily 1-Thyroxine Secretion Rate of Ewes at Controlled Ambient Temperatures and Artificial Light Conditions

Ambient Temperature	Hours Artificial Light	df	Sum of x	Sum of y	Sum of x^2-c.t.	Sum of y^2-c.t.	Sum of xy-c.t.	r	Level of Significance	b	Estimated Daily Secretion Rate in mg.*
50° F	8	3	.09	257.98	.0018	113.80	.4521	.98	.01	251.17	.086
50° F	8	4	.18	359.13	.0044	354.37	1.0573	.85	.03	240.30	.088
50° F	8	4	.18	354.89	.0044	22.51	.1567	.50	.50	35.61	.362
50° F	8	4	.18	392.07	.0044	245.00	.3292	.32	.70	74.82	.072
50° F	8	6	.45	528.87	.0157	385.70	2.1937	.61	.40	139.73	.160
50° F	8	4	.18	358.17	.0044	114.15	.6964	.99	.01	158.27	.111
Intra-Class Correlation		25	1.26	2251.11	.0351	1235.53	4.8854	.74	.01	139.15	.122
90° F	8	2	.01	187.71	.00005	30.81	.0412	.99	.01	824.00	.012
90° F	8	3	.03	274.20	.00020	172.58	.0326	.18	.80	163.00	.063
90° F	8	3	.03	252.34	.00020	78.81	.0854	.69	.38	427.00	.047
90° F	8	3	.03	293.52	.00020	54.69	.1035	.99	.01	518.00	.014
90° F	8	3	.03	268.51	.00020	171.52	.0782	.43	.60	391.00	.036
90° F	8	4	.06	346.64	.00035	527.11	.1431	.33	.70	408.86	.048
Intra-Class Correlation		18	.19	1622.92	.00120	1035.52	.4840	.43	.06	403.33	.035

*Milligrams 1-thyroxine secreted daily per 100 pounds body weight.

Appendix I

One Day Per Cent Uptake of I^{131} by the Thyroid Gland of Ewes
Under Controlled Ambient Temperature and Artificial Light Conditions

Hours of Artificial Light	Ambient Temperature					
	50° F	55° F	85° F	90° F	Total	Average
8	11.17	8.11	4.02	9.14		
8	7.71	11.95	8.63	6.02		
8	11.99	4.72	9.33	1.44		
8	8.09	13.70	16.62	3.62		
8	8.90	11.08	10.26	4.93		
8	8.05	12.36	12.65	2.64		
Total	55.91	61.92	61.51	27.74	207.13	
Average	9.32	11.62	10.25	4.63		8.63
12	4.37	5.69	7.91	4.90		
12	5.84	6.26	4.26	5.81		
12	7.60	7.73	9.19	7.59		
12	5.36	9.86	6.67	5.32		
12	4.58	7.91	7.15	6.28		
12	7.37	7.68	3.38	5.56		
Total	35.12	45.13	38.56	35.46	154.27	
Average	5.85	7.52	6.43	5.91		6.43
16	5.50	13.11	7.46	5.43		
16	9.54	7.69	11.62	9.38		
16	4.95	8.20	9.06	4.33		
16	4.92	4.61	8.09	4.92		
16	5.56	10.11	7.07	8.22		
16	4.72	11.57	11.57	7.76		
Total	35.19	55.29	54.87	40.04	185.39	
Average	5.87	9.22	9.15	6.67		7.73
Total	126.22	162.34	154.94	103.29	546.79	
Average	7.01	9.02	8.61	5.74		7.59

Appendix J

Three Day Per Cent Uptake of I^{131} by the Thyroid Gland of Ewes Under Controlled Ambient Temperature and Artificial Light Conditions

Hours of Artificial Light	Ambient Temperature 50° F	55° F	85° F	90° F	Total	Average
8	17.26	7.81	4.38	17.24		
8	11.50	6.48	8.76	16.11		
8	18.92	5.14	12.06	6.84		
8	13.38	15.37	13.02	8.50		
8	13.13	10.42	9.65	8.03		
8	12.26	14.10	14.86	4.19		
Total	86.45	59.32	62.33	60.91	269.01	
Average	14.41	9.89	10.39	10.15		11.21
12	11.28	8.82	11.07	6.40		
12	9.87	10.07	6.14	8.42		
12	10.27	10.18	13.50	10.11		
12	8.74	13.82	7.33	11.33		
12	8.07	8.54	9.49	7.20		
12	12.19	8.70	8.12	9.56		
Total	60.42	60.13	55.65	53.02	229.22	
Average	10.07	10.02	9.27	8.84		9.55
16	9.79	20.33	14.98	9.02		
16	16.02	9.00	15.39	14.75		
16	8.05	13.64	13.77	10.18		
16	6.57	7.61	12.24	10.44		
16	8.52	14.41	13.53	14.01		
16	5.88	15.93	18.37	15.63		
Total	54.83	80.92	88.68	74.03	298.46	
Average	9.14	13.49	14.78	12.34		12.44
Total	201.70	200.37	206.66	187.96	796.69	
Average	11.20	11.13	11.48	10.44		11.07

Appendix K

Maximum Per Cent Uptake of I^{131} by the Thyroid Gland of Ewes
Under Controlled Ambient Temperature and Artificial Light Conditions

Hours of Artificial Light	Ambient Temperature				Total	Average
	50° F	55° F	85° F	90° F		
8	17.26	7.81	8.13	20.68		
8	12.34	11.40	10.11	19.09		
8	19.36	5.14	12.06	6.84		
8	13.38	15.37	16.83	9.35		
8	15.08	12.19	11.25	8.14		
8	13.63	14.28	15.58	4.20		
Total	91.05	66.19	73.96	68.30	299.50	
Average	15.18	11.03	12.33	11.38		12.48
12	12.48	8.82	11.56	6.49		
12	10.16	10.41	6.15	8.42		
12	10.27	10.23	13.50	10.24		
12	8.74	13.82	8.18	11.33		
12	8.07	8.71	9.83	8.74		
12	14.09	8.76	8.12	10.56		
Total	63.81	60.75	57.34	55.78	237.68	
Average	10.64	10.13	9.56	9.30		9.90
16	9.79	21.91	18.96	9.95		
16	19.68	10.62	16.78	15.21		
16	8.05	13.64	16.49	10.72		
16	7.24	9.75	16.34	10.72		
16	8.52	15.01	16.93	15.03		
16	6.35	17.26	22.24	15.63		
Total	59.63	88.19	107.74	77.26	332.82	
Average	9.94	14.70	17.96	12.88		13.87
Total	214.49	215.13	239.04	201.34	870.00	
Average	11.92	11.95	13.28	11.19		12.08

Appendix L

Zero Time Per Cent Uptake of I^{131} by the Thyroid Gland of Ewes Under Controlled Ambient Temperature and Artificial Light Conditions

Hours of Artificial Light	Ambient Temperature					
	50° F	55° F	85° F	90° F	Total	Average
8	21.97	8.93	5.68	25.36		
8	16.11	22.25	14.64	18.58		
8	24.65	6.39	14.60	7.85		
8	14.60	17.22	18.85	10.25		
8	21.21	14.31	13.92	9.15		
8	17.36	17.74	18.02	6.06		
Total	151.90	86.74	85.71	77.25	365.60	
Average	25.32	14.46	14.29	12.88		15.23
12	14.55	12.68	14.47	6.64		
12	15.25	14.01	10.40	7.95		
12	10.21	12.19	12.73	9.87		
12	9.83	14.00	8.68	11.19		
12	9.15	9.01	12.22	11.25		
12	28.76	9.74	10.78	10.60		
Total	87.75	71.63	69.28	57.50	286.16	
Average	14.63	11.94	11.55	9.58		11.92
16	12.81	21.72	22.92	11.53		
16	23.06	10.18	22.32	21.54		
16	9.43	20.60	16.25	11.08		
16	8.13	9.11	22.63	17.81		
16	10.29	23.21	18.64	17.64		
16	7.85	21.17	24.24	20.82		
Total	71.57	105.99	127.00	100.42	404.98	
Average	11.93	17.67	21.17	16.74		16.87
Total	275.22	264.36	281.99	235.17	1056.74	
Average	15.29	14.69	15.67	13.07		14.68

Appendix M

Day of Maximum Per Cent Uptake of I^{131} by the Thyroid Gland of Ewes Under Controlled Ambient Temperature and Artificial Light Conditions

Hours of Artificial Light	Ambient Temperature 50° F	55° F	85° F	90° F	Total	Average
8	3	3	5	4		
8	4	5	5	4		
8	4	3	3	3		
8	3	3	4	5		
8	5	4	5	4		
8	5	5	4	5		
Total	24	23	26	25	98	
Average	4.0	3.8	4.3	4.2		4.08
12	5	3	4	2		
12	5	4	4	3		
12	3	4	3	2		
12	3	3	2	3		
12	3	2	2	2		
12	4	2	3	4		
Total	23	18	18	16	75	
Average	3.8	3.0	3.0	2.7		3.13
16	3	4	4	4		
16	4	4	4	5		
16	3	3	4	2		
16	4	5	4	2		
16	3	4	4	4		
16	2	4	4	3		
Total	19	24	24	20	87	
Average	3.2	4.0	4.0	3.3		3.63
Total	66	65	68	61	260	
Average	3.67	3.61	3.78	3.39		3.61

Appendix N

Twenty Day Body Weight Gains of Ewes Fed ad. lib.
Under Controlled Ambient Temperature and Artificial Light Conditions

Hours of Artificial Light	Ambient Temperature					
	50° F	55° F	85° F	90° F	Total	Average
8	10	4	-1	3		
8	3	5	8	2		
8	3	21	8	8		
8	8	3	5	2		
8	6	12	8	2		
8	13	7	2	4		
8	8	15	3	13		
Total	51	67	33	34	185	
Average	7.28	9.57	4.71	4.86		6.61
12	4	2	4	1		
12	6	9	9	5		
12	8	12	12	0		
12	3	6	5	2		
12	4	8	12	2		
12	8	4	13	2		
12	2	8	5	0		
Total	35	49	60	12	156	
Average	5.00	7.00	8.57	1.71		5.57
16	9	4	-4	5		
16	0	9	13	5		
16	6	-2	9	7		
16	12	7	3	8		
16	5	6	2	7		
16	8	10	10	2		
16	13	8	10	3		
Total	55	42	43	37	175	
Average	7.60	6.00	6.14	5.30		6.25
Total	139	158	136	83	516	
Average	6.62	7.52	6.48	3.95		6.14

Appendix O

Twenty Day Feed Consumption Per Pound of Body Weight of Ewes Fed ad. lib. Under Controlled Ambient Temperature and Artificial Light Conditions

Hours of Artificial Light	Ambient Temperature 50° F	55° F	85° F	90° F	Total	Average
8	.62	1.00	.53	.50		
8	.76	.99	1.11	.63		
8	.56	1.32	.98	1.11		
8	.86	.93	.91	.88		
8	.72	1.23	.88	.97		
8	.53	1.01	.87	.87		
8	.71	1.13	.72	.80		
Total	4.76	7.61	6.00	5.76	24.13	
Average	.68	1.09	.86	.82		.86
12	.61	.78	.68	1.00		
12	.57	.96	.96	.70		
12	.75	.83	.73	.57		
12	.61	.92	.81	.71		
12	.84	.80	.83	.75		
12	.82	.92	.95	.74		
12	.50	1.02	.50	.70		
Total	4.70	6.23	5.46	5.17	21.56	
Average	.67	.89	.78	.74		.77
16	.90	.86	.64	.86		
16	.57	1.16	.88	.89		
16	.71	.63	.65	.62		
16	.99	1.19	.96	.86		
16	.67	1.09	.79	.89		
16	.82	1.19	.91	.69		
16	.98	1.15	.86	.78		
Total	5.64	7.27	5.69	5.59	24.19	
Average	.81	1.04	.81	.80		.86
Total	15.10	21.11	17.15	16.52	69.88	
Average	.72	1.02	.82	.79		.83

Note: The weight of all ewes was adjusted to 70 pounds by the use of the following formula (Brody, "Bioenergetics and Growth"):

Adjusted weight = 70 + (deviation from 70)$^{.73}$

Appendix P

Pounds of Water Consumption Daily by Ewes
Under Controlled Ambient Temperature and Artificial Light Conditions

Hours of Artificial Light	Ambient Temperature					
	50° F	55° F	85° F	90° F	Total	Average
8	5.14	7.20	4.29	6.14		
8	5.40	8.53	9.99	6.82		
8	3.81	13.72	10.63	12.71		
8	7.70	7.70	7.72	10.29		
8	3.28	9.73	9.82	10.29		
8	4.72	7.96	12.00	11.78		
8	4.93	11.12	8.97	8.37		
Total	34.98	65.96	63.42	66.40	230.76	
Average	5.00	9.42	9.06	9.49		8.24
12	3.10	7.78	6.51	13.02		
12	8.93	10.14	12.71	10.23		
12	4.03	9.20	10.66	8.93		
12	4.49	9.92	10.54	8.99		
12	6.99	9.09	8.68	10.51		
12	6.10	8.06	9.86	13.33		
12	4.96	11.47	4.34	9.61		
Total	33.64	65.66	63.30	74.62	237.22	
Average	4.81	9.38	9.04	10.66		8.47
16	7.25	7.56	6.38	8.92		
16	4.19	11.08	11.43	9.83		
16	6.35	7.31	6.78	6.23		
16	8.92	12.05	12.95	10.16		
16	4.12	11.13	7.53	9.26		
16	7.00	11.39	9.52	7.04		
16	8.89	8.12	9.48	8.18		
Total	46.72	68.64	64.07	59.62	239.05	
Average	6.67	9.80	9.15	8.52		8.54
Total	115.34	200.26	190.79	200.64	707.03	
Average	5.49	9.54	9.09	9.55		8.42

Note: Water was available ad. lib. for all groupd of ewes except the 50° F group which was offered water every twelve hours in order to control humidity. This may account for the differences shown by the 50° F group.

Appendix Q

Rectal Body Temperature of Ewes
Under Controlled Ambient Temperature and Artificial Light Conditions

Hours of Artificial Light	Ambient Temperature 50° F	55° F	85° F	90° F	Total	Average
8	102.9	103.7	102.9	102.0		
8	102.7	103.1	105.1	102.6		
8	102.7	103.7	104.1	102.9		
8	102.9	103.1	104.2	103.2		
8	102.5	103.6	104.2	102.9		
8	102.6	103.2	104.2	103.2		
8	102.8	103.9	103.9	102.7		
Total	719.1	724.3	728.6	719.5	2891.5	
Average	102.7	103.5	104.1	102.8		103.3
12	102.1	102.2	102.8	104.4		
12	101.8	102.8	103.8	104.1		
12	103.0	102.7	103.9	103.8		
12	102.8	102.9	103.6	103.2		
12	102.1	103.2	104.2	104.0		
12	102.6	103.2	103.7	103.8		
12	102.6	102.7	102.5	102.9		
Total	717.0	719.7	724.5	726.2	2887.4	
Average	102.4	102.8	103.5	103.7		103.1
16	102.0	103.1	102.8	103.3		
16	102.1	103.3	104.2	103.4		
16	102.0	102.4	103.1	102.8		
16	102.5	103.2	104.7	103.3		
16	102.1	103.6	103.8	103.8		
16	102.4	103.1	104.0	102.6		
16	102.4	103.5	103.3	102.9		
Total	715.5	722.2	725.9	722.1	2885.7	
Average	102.2	103.1	103.7	103.2		103.1
Total	2151.6	2166.2	2179.0	2167.8	8664.6	
Average	102.5	103.1	103.8	103.2		103.1

Appendix R

Respiration Rate of Ewes
Under Controlled Ambient Temperature and Artificial Light Conditions
(Flank Movements Per Minute)

Hours of Artificial Light	Ambient Temperature 50° F	55° F	85° F	90° F	Total	Average
8	42	61	135	75		
8	40	90	186	89		
8	31	89	154	102		
8	46	114	159	154		
8	36	60	147	139		
8	33	99	148	142		
8	42	92	109	89		
Total	270	604	1039	790	2703	
Average	39	85	148	113		97
12	64	49	111	141		
12	59	55	111	150		
12	59	43	129	144		
12	42	55	150	131		
12	43	50	155	135		
12	56	41	134	152		
12	37	49	91	123		
Total	360	342	881	976	2559	
Average	51	49	126	139		91
16	42	48	131	144		
16	35	124	168	156		
16	40	90	145	137		
16	57	100	201	139		
16	34	105	159	181		
16	40	128	156	80		
16	37	137	123	133		
Total	285	732	1083	970	3070	
Average	41	105	155	139		110
Total	915	1678	3003	2736	8332	
Average	44	80	143	130		99

Appendix S

The Determination of Iodine in Thyroid Glands*

Reagents:

1. A. R. Quality NaOH and KNO_3 for the alkaline fusion
2. H_3PO_4, 85%
3. Methyl orange indicator solution
4. Sodium bisulfite, 10% solution, A. R.
5. Bromine water, saturated. A. R.
6. Sodium salicylate, 5% solution
7. Potassium iodide, A. R., 10% solution freshly prepared immediately before titrating samples.
8. 0.5% starch solution (keep refrigerated).
9. Standard Iodate Solution, 0.1 N: Weigh 3.5670 grams of potassium iodate, dissolve in a small amount of water, transfer the solution quantitatively to a liter volumetric flask and dilute to the mark with water. When treated with an excess of KI and H_2SO_4 this solution liberates iodine equivalent to its volume of 0.1 N. The solution is used to standardize the 0.1 N. sodium thiosulfate. If kept in a cool place and in a glass stoppered bottle the solution will retain its strength almost indefinitely.
10. Standard Sodium Thiosulfate Solution: In approximately 0.1 N. stock solution of sodium thiosulfate, $Na_2S_2O_3.5\ H_2O$ is prepared by dissolving 24.820 grams in water and diluting to the mark in a 1000 ml. volumetric flask. The addition of 10 ml. of 0.1 N. NaOH per liter greatly increases its stability.

*Analytical procedure for method published by E. P. Reineke, C. W. Turner, G. O. Kohler, R. D. Hoover and M. B. Beezley. The determination of thyroxine in iodinated proteins having thyroidal activity. J. Biol. Chem. 161:599-611, 1945.

Appendix E (continued)

11. The 0.1 N. thiosulfate is standardized against potassium iodate after it reacts with an excess of potassium iodide and sulfuric acid. The procedure is as follows: To 20 cc. of standard 0.1 N. Iodate solution in a 500 ml. Erlenmeyer flask add about 200 ml. of distilled water and 10 ml. of a 10% solution of potassium iodide and about 5 cc. of 1 N. sulfuric acid. The thiosulfate is added by means of a burette. When the iodine color has faded to a pale yellow or straw color, 1 cc. of starch solution is added and the titration is continued until the blue color has entirely disappeared.

$$\frac{\text{cubic centimeters of 0.1 N. iodate}}{\text{cubic centimeters of thiosulfate}} = \text{factor for 0.1 N. thiosulfate}$$

From this solution a 0.005 N. sodium thiosulfate solution is prepared. If the NaOh is added the solution retains its titre for several days. If the NaOH is omitted it must be prepared daily.

Procedure

Place an accurately weighed thyroid, dissected free of all adhering tissue, into a nickel crucible. To the content of the crucible add 5.0 grams of sodium hydroxide pellets and 2 ml. of distilled water. Then moisten the film of sediment remaining on the sides of the crucible by tilting. Evaporate the water by cautiously heating over a low flame. Then place the cover on the crucible and heat strongly enough to keep the melt liquid. When nearly clear add a small crystal of KNO_3. Continue the heating. Repeat until no more efferscence is observed after adding KNO_3. After cooling dissolve the melt by filling the cruicible about two-thirds full of distilled water and heating cautiously. Transfer quantitatively to a 500 ml. Erlenmeyer flask, using about 150 ml. of distilled water. Add 6 drops of methyl orange solution, 1.0 ml. of 10% sodium bisulfite solution, and 85% H_3PO_4 until the color is faintly pink. Add

Appendix S (continued)

Procedure (continued)

enough bromine water to color the solution strongly yellow, add glass beads and boil briskly until clear. (This will take about 10 minutes.) Add 5 drops of 5% sodium salicylate solution and cool in running water to about 20° C. Insufficient cooling causes an indistinct end point. Add 5.0 ml. of freshly prepared 10% KI solution and 5 ml. of 85% H_3PO_4. Titrate the iodine with 0.005 N. $Na_2S_2O_3$ solution. Use a starch solution as an indicator. (The $Na_2S_2O_3$ is freshly prepared by diluting it in the ratio of 5.0 ml. of 0.1 N. $Na_2S_2O_3$ per 100 ml. of distilled water.) Calculation: 1 ml. of 0.005 N. $Na_2S_2O_3$ solution is equivalent to 0.106 mg. of iodine in the sample.

$$\text{Percent iodine} = \frac{\text{weight of iodine}}{\text{weight of thyroid}} \times 100$$

Appendix T

Effect of Ambient Temperature and Artificial Light on Weight and Iodine Content of Thyroid Gland

Ambient Temperature	Hours of Artificial Light	Weight of Ewe (lbs.)	Weight of Thyroid (grams)	Total Iodine Content (mg.)	Percent Iodine Content
50° F	8	103	2.2825	2.42	0.106
50° F	12	79	2.2071	3.40	0.154
50° F	16	88	3.2254	4.55	0.141
55° F	12	114	1.8993	3.48	0.183
55° F	16	81	1.7220	2.22	0.129
85° F	12	93	2.1707	3.17	0.146
85° F	16	79	2.3410	47.59	2.033
90° F	8	108	2.1109	3.31	0.157
90° F	12	91	2.0485	2.72	0.133
90° F	16	143	2.0776	3.26	0.157

Appendix U

Effect of Ambient Temperature and Artificial Light on Epithelial Cell Height of Thyroid Gland

Ambient Temperature	Hours of Artificial Light	Average Height of Epithelial Cells (Micra)
50° F	8	10.76
50° F	12	10.98
50° F	16	10.63
55° F	12	7.25
55° F	16	10.82
85° F	12	6.37
85° F	16	9.22
90° F	8	6.70
90° F	12	6.04
90° F	16	6.42

Appendix V

Testing Difference Between Two Correlation Coefficients

Convert r to z

Variance in z $= \frac{1}{n-3}$

Variance of $z_1 - z_2 = \frac{1}{n_1-3} + \frac{1}{n_2-3}$

Standard deviation of $z_1 - z_2 = \frac{1}{n_1-3} + \frac{1}{n_2-3}$

$t = \frac{z_1 - z_2}{\text{Standard deviation of } z_1 - z_2}$

Look up t with infinite degrees of freedom