AN ASSESSMENT OF THE PHYSIOLOGICAL REACTIONS OF SOWS TO THEIR ENVIRONMENT IN MANAWATU, NEW ZEALAND.

by

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Being a Thesis presented in partial fulfilment of the requirements for the Degree of Master of Agricultural Science.

Massey Agricultural College,
University of New Zealand.
Nov., 1959.

"Leadership devolves almost automatically upon the pigs, who are on a higher intellectual level than the rest of the animals."

George Orwell.

A C K N O W L E D G M E N T S.

The writer wishes toexpress his sincere thanks and appreciation to Mr. A.C. Dunkin, Senior Lecturer, Dairy Husbandry Department, Massey College, for his invaluable advice and guidance in the preparation of this thesis.

Thanks are due to Mr. R. E. Munford, also of the Dairy Husbandry Department, Massey College and more especially to Mr. A.C. Glenday, Statistician, D.S.I.R., Palmerston North, on his unfailing courtesy at all times in the preparation of the statistical data.

In conclusion the writer wishes to convey his particular indebtedness to the Librarian, Miss Mary G. Campbell and her staff, for the use of the library facilities and making available references on interloan; to Mr. D.F.G. Orwin for photographic work and to the Piggery staff and numerous students who helped in the measurement and collection of data. Special thanks are due to Mrs. S. McHugh for her patience in typing this manuscript.

R. K. N.

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GENERAL INTRODUCTION

A general recognition of the problem of animal climatological studies to a scientific approach is recent. Animal husbandmen are aware that economic pressures of various kinds are forcing the production of livestock into climatic environment that are increasingly more remote from that considered ideal for optimal production and feed utilization.

An animal's efficiency and general well-being are profoundly influenced by the environment in which it lives. Prolonged exposure to very high temperatures, especially when performing physical work (horses and bullocks used as draught animals) may lead to heat stroke or heat collapse; and even at temperatures well below those at which such acute troubles may arise, there is disinclination to forage for themselves and appetite is often impaired; consequently there is a substantial loss of productive efficiency viz., milk production, weight gains in pigs, sheep and cattle. Similarly, low temperatures prove equally detrimental. According to Davidson (1948) sows suffer pain and inconvenience if their stocked udders drag through the mud and then are exposed to cold wind. Lucas (1954) reported liver disease in pigs reared in the damp cold floor in a cold building. Cold and wet conditions have definitely adverse effects though information is lacking about the precise aetiology of the coughing often noticed in communal pig houses and about the immediate cause of unthriftiness of young pigs born there in the winter months. Extremes of temperatures should therefore be avoided if livestock are required to maintain a high pitch of efficiency.

Comprehensive reviews of literature on the environmental physiology of domestic animals have been published by Lee and Phillips (1948), Findlay and Beakley (1954), Brody (1956) and McDowell (1958). However, most of the work has been done with cattle and only in recent years attention has been focussed on other types of livestock. The pig is one such animal.

P A R T I

CHAPTER I

1. Scope of this study.

In New Zealand the outstanding feature of the pig industry is its close associations with dairying. This fact is well established by McMeekan (1944) i.e. "The North Island with 95% of the total dairy cows also carries 89% of the total pigs." From this statement it would appear that the pig has been placed in an environment that is suited to cattle. Cattle have proved themselves in this area as efficient converters of plant-feeding stuffs into animal products. The pig on the other hand, is kept to consume the perishable milk by-products for which man power and transport to centres of populations are not always available. The pig can make use of such by-products efficiently.

Another feature of the industry is that the adult pig spends a good deal of time out of doors, foraging. Winters are severe in certain parts of the country, temperatures below 40°F. are not uncommon. Summers are warm with temperatures above 75°F., and yet housing in general, especially of dry stock, is not at all adequate. Heitman and Hughes (1949, 1958) have studied the reaction of the pig to environmental temperature under controlled conditions in a psychrometric chamber. They report that the zone of thermo-neutrality for the pig lies between 55°F.- 75°F., depending on the liveweight. Temperature permitting, maximum gains decrease gradually with increasing liveweight within this range. Shanks (1942) maintains that sudden drops in environmental temperature caused outbreaks of pneumonia and paratyphoid; huddling, fighting and savaging were common features among pigs where houses were intensely cold. His information was obtained from a farm where the temperature varied from 68°F. to 44°F. in 24 hours. Such a range of temperature is not uncommon in New Zealand.

In recent years there has been a general expansion of the pig industry in New Zealand. If the country is to reap the maximum benefit from such an enterprise then detail investigations into all aspects of housing to health and productivity under controlled experimental conditions is warranted. And before such an investigation is undertaken, studies of the pig's reaction to varying atmospheric temperatures under New Zealand conditions is desirable. It is true to say that little is known of fundamental requirements for optimum environmental conditions under New Zealand system of pig management.

It is the object of this project to look into techniques for assessing some of the physiological reactions of thepigs to their environment under field conditions and to make some evaluations of these reactions in sows under conditions mentioned above.

2. Climate of New Zealand with particular reference to Manawatu.

Schwass (1955) in his review on "The Climate of New Zealand" cites Kidson (1950) to say that the main factors which control New Zealand's climate are, in order of importance:

(a) Latitude
(b) Oceanic surrounding
(c) High relief.

(a) Latitude:

New Zealand lies in the temperate zone between the high-pressure belt of the sub-tropics and the low pressure trough of the Southern ocean, but nearer to the former. Westerly winds prevail and rapid weather fluctuations are caused by a series of anticyclones and depressions which move continuously from West to East. As depressions are frequent and atmosphere is laden with moisture during itstravel over the Tasman sea, the rainfall over much of the country is high.

(b) Ocean surroundings:

New Zealand is a narrow strip of land and in general no part of the country is very far from the sea. The small area of the country prevents extreme seasonal or irregular variations in temperature and that is why the climate is often described as 'insular' of 'oceanic'.

(c) High relief:

The high ranges cause strong vertical movements and this mixing of various layers modifies the distribution of temperature and water vapour through these layers. Consequently the effects produced include an irregular distribution of rainfall, an absence of large continuous sheets of low cloud, a high percentage of bright sunshine, and a large diurnal variation in temperature.

Manawatu lies in the "middle of New Zealand" and this region conforms so clearly to the average conditions associated with New Zealand as a whole. Briefly, the outstanding features of this climate is summarized as follows, Garner (1957):-

(i) This region displays a comparatively large mean diurnal range of temperature. For Palmerston North, this is 15.3^{o}F.

(ii) It is subject to very cold or very hot weather conditions. Temperatures above 80^{o}F. in summer is not unusual. However, the frequency of low temperatures is greater than that of high ones. Low temperatures moreover, can be caused by an out-of-season cold snap.

(iii) As a general rule, precipitation is evenly spread throughout the year. There is a maximum in winter, and a minimum in summer or autumn. Manawatu experiences the lowest mean annual and monthly variability in the middle of New Zealand, since this area derives the greater part of its relatively low rainfall totals from westerly winds. Average precipitations is about 30 inches.

(iv) On the average, between 125 and 175 rainy days a year are experienced and much of precipitation is derived from cold frónts.

(v) Sunshine, like rainfall is plentiful - 1839 sunshine hours per year or 41% of the total possible hours.

(vi) Winds are gusty in character and a rather high proportion of winds are strong ones.

CHAPTER II

REVIEW OF LITERATURE.

Heat Regulations.

(a) Poikilothermisms and Homoiothermisms.

Vertebrate animals may be divided into two great classes as regards the relation of the body temperature to that of the environmental temperature: poikilothermal or "cold-blooded" animals whose body temperatures closely follow that of their environment, and almost the only means the animals have of avoiding the consequences of unfavourable environments are avoiding those environments. These impose a severe restriction upon the dreedom of their lives; the homeothermal or "warm-blooded" animals are those whose body temperatures are largely independent of that of the environments. Mammals and birds are considered homeothermal, whereas other animals are poikilothermal. According to Dukes (1947) some mammals are homeothermal only under favourable temperature conditions, becoming poikilothermal when the surrounding temperature is cold.

Homeotherms have an elaborately developed heat-regulating device which enables them to maintain, under any ordinary conditions, a relatively constant body temperature (which vary slightly from species to species) regardless of the surrounding environmental temperatures. Such animals are able to carry on their usual activities under a wide range of external temperature. In order to carry on their usual activities (maintain constant body temperature, cardio-respiratory activities, and muscle tone) their heat loss or thermolysis. When the environment is hot, the problem is how to dissipate heat produced in the body; when the environment is cold, the problem is how to conserve heat and how to produce enough extra heat to keep the body temperature constant despite the unavoidable heat losses. A diagram is presented

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Homeotherms have an elaborately developed heat-regulating device which enables them to maintain, under any ordinary conditions, a relatively constant body temperature (which vary slightly from species to species) regardless of the surrounding environmental temperatures. Such animals are able to carry on their usual activities under a wide range of external temperature. In order to carry on their usual activities (maintain constant body temperature, cardio-respiratory activities, and muscle tone) their heat loss or thermolysis, must equal their heat production or thermogenesis. When the environment is hot, the problem is how to dissipate heat produced in the body; when the environment is cold, the problem is how to conserve heat and how to produce enough extra heat to keep the body temperature constant despite the unavoidable heat losses. A diagram is presented in a review by Findlay and Beakley (1954) showing the principal methods by which heat is produced, gained and lost in cattle. With slight modifications of this diagram, it would apply to our other domestic animals.

It will be clear from this diagram then, that in the animal body the production, absorption and emission heat are all intimately inter-related.

(b) Heat Exchange.

The warm-blooded animal may be regarded for basic discussion as having a central core of tissue at uniform "body temperature." Surrounding this is a shell of tissue through which temperature progressively falls as the surface is approached and through which heat flows to the surface by conduction and by convection through the blood stream (Lee and Phillips, 1948).

From the surface of the animal, heat is exchanged with the environment by radiation and conduction, i.e. heat flows by these physical processes in whichever direction the difference in temperature lies and according to simple physical laws. Heat is also lost from the surface by evaporation of water transuded through the skin (true insensible perspiration), sweat, or water acquired by licking, wallowing or other special means.

Immediately surrounding the animal, is a layer of air through which the temperature progressively changes until it reaches that of ambient air and by which heat flows by conduction and by convection provided through air movement. The effective thickness of layer is determined by the rate of air movement over the surface.

The respiratory tract may be looked upon as a special part of the body surface with which air exchanges heat by conduction and from which heat is lost by evaporation of body water.

(i) Heat Production.

Heat is produced by oxidation in the active protoplasm of the body. Muscle and gland, making up the greater part of the active tissues, are therefore the principal seats of heat production. The amount of heat produced in a muscle or gland is not the same at all times. It varies directly with the degree of activity of the structure.

Heat production may be increased by several different factors. They may be summarized as follows:

1. Ingestions of food increases it through the so-called heat increment of feeding or the stimulating effect of food.

2. Heat production can vary with the posture of the animal. In a cow for example, the energy expended in standing is about 9% greater than it is when the animal is lying down and the energy required in getting up anddown may amount to about 12 Cals/100 lb.body weight (Findlay and Beakley, 1954). In the same way it has been shown that in an animal foraging for food still further increases occur due to muscular activity.

3. The state of productivity of the animal for example, milk production in the cow involves increased heat production. Findlay (1950) states that a non-lactating, resting dairy cow might produce heat at the rate of 12,000 cal/day, but the same cow producing four gallons of milk per day might produce twice the amount of that heat.

4. Solar radiation and heat from the surrounding may be absorbed and this depends markedly on the type and color of the coat.

Heat production of an animal varies with the environmental temperature (Brody, 1945). A diagram showing the type of variation which occurs has been published by Brody (1945) and is reproduced in Fig. 1.

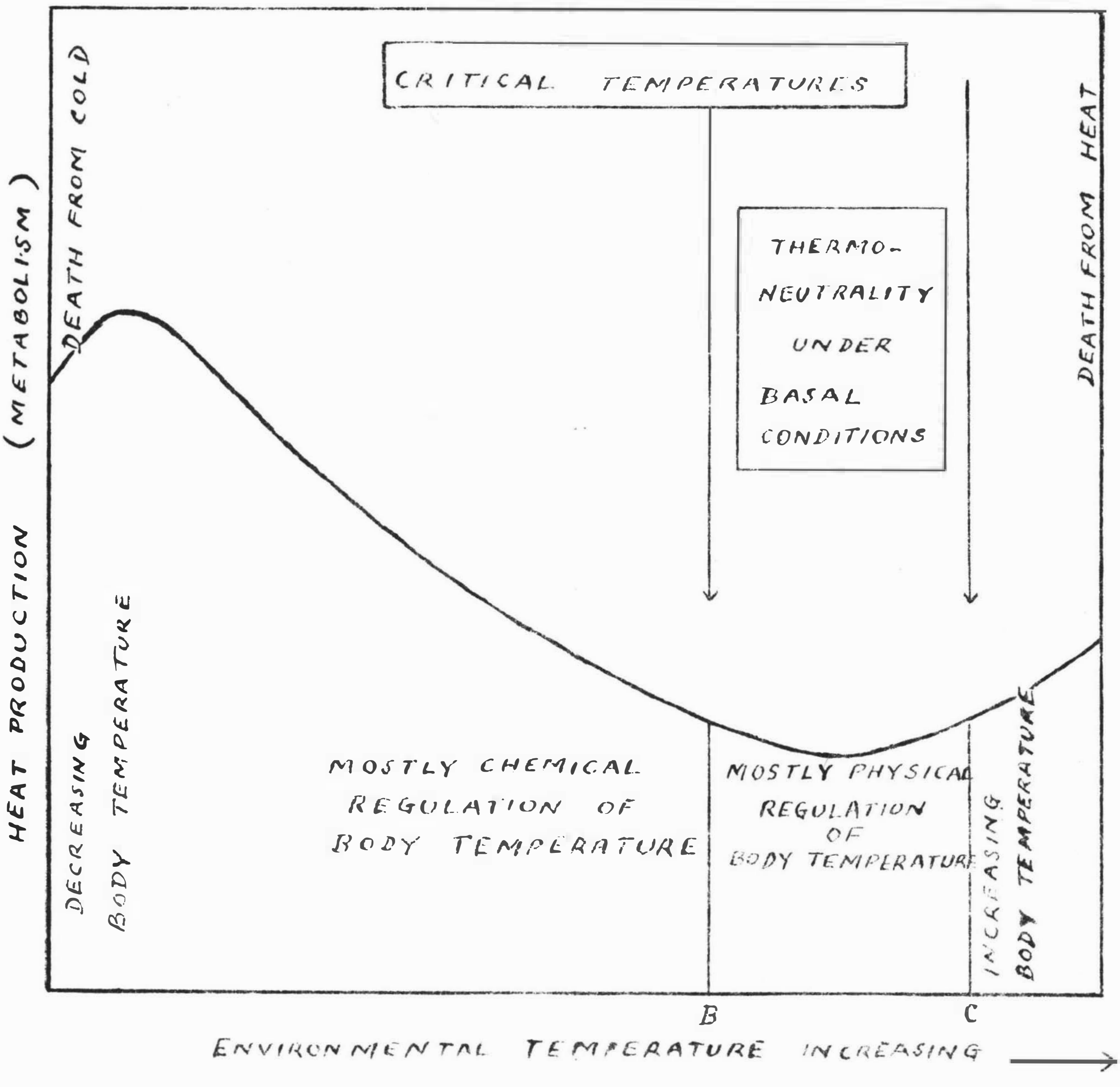


FIG 1. The influence of environmental temperature on heat production in homeothermes. Between the critical temperatures B and C - the "comfort zone" for man - the animal regulates its body temperature without appreciably altering its heat production. The value of B is about 16°C. for a steer and about 21°C. for pigs and poultry (Adapted form Brody, 1945, 1948.)

When the environmental temperature is very low heat production reaches its highest value, which is known as the "summit metabolism", but as there is still a further decrease the environmental temperature, body temperature decreases also and serious consequences follow resulting in the death of the animal. The high value of the summit metabolism represents the extra effort necessary at very low temperatures to maintain normal body temperature. As the environmental temperature increases from a low value to one to which the animal is more naturally accustomed, heat production steadily declines. In this zone the body-temperature is regulated mainly by such processes as shivering, altering the intensity of the thyroid-adrenal function and changing the calibre of blood vessels. These devices are called chemical methods of regulation. With still further increases in environmental temperature the zone of thermoneutrality (the so-called comfort zone for man) is reached. This zone of thermo-neutrality or thermal neutrality is the environmental temperature at which heat loss from the body is equal to the minimum heat production i.e. in this zone the heat production does not change much and the heat balance is regulated principally by physical means such as evaporation of moisture from the skin and lungs, increasing or decreasing the circulation of blood in the skin and seeking shade or sunshine as the case may be. As the environmental temperature increases beyond what has been termed the upper critical temperature, the animal begins to have difficulty in ridding itself of excess heat and its body temperature rises. It begins to pant and its respiration rate increases markedly. Finally, at the upper limit where the environmental temperature is exceedingly high, death occurs.

(ii) Heat Loss.

In a temperate climate, an animal has little difficulty in ridding itself of the heat it produces from its food as a result of its activity and productivity. Only a small solar heat load is imposed on the animal and the ambient air temperature is nearly always below that of the animal's rectal temperature, so that the normal physical methods of dissipating heat are adequate. In the tropics, however, an entirely different situation exists. The solar heat load can be very great and may amount to two or three times the amount of heat actually produced by the animal in that period (Riemerschmid, 1943a) and since the temperature of the surroundings, the air temperature and often the humidity are high while air movement may be low, the usual physical methods of losing heat by radiation, conduction, convection and evaporation are greatly restricted. Heat, we know is constantly being produced in the body as a result of physiological oxidations. This heat together with the heat absorbed from solar radiation must be dissipated if the animal is to survive, otherwise the temperature of the body would rise to such a height that life would no longer be possible.

The first thing the animal does under such conditions is reduce its activity and food intake. This condition has been shown by Ragsdale et al. (1948). In cattle it was shown that reduced intake resulted in reduction in milk production (similarly in young animals, growth was affected). Heat production is lowered in this way.

Ordinarily, heat is lost from the body in the following ways:

1. Radiation, conduction and convection.
2. Vapourization of water from the skin and respiratory passages.
3. Excretions from feces and urine.

The first two ways are important and are discussed here further.

Radiation.

The electro-magnatic waves excited by temperature are referred to as thermal radiation. Such radiation is given off by all matter. Heat loss by radiation from the animal body is given by the equations

$$Hr = Ap(e_1T_1^4 - e_2T_2^4)$$

in which A = the effective or profile surface area of the animal.
T_1 = the absolute temperature of the animal's surface.
T_2 = the absolute temperature of the surrounding surfaces.
p = dimensional constant in the Stefan-Boltzmann Law which states that the emissive power is proportional to the fourth power of theabsolute temperature.
e_1 = the emissivity, virtually 0.95 for animal or human skin.
e_2 = the emissivity of the surroundings.

Radiation loss is therefore related to the surface area of the animal i.e. an animal in a huddled posture will have less surface area exposed and will therefore lose less heat in this manner as compared to the animal that is spread-eagled (Findlay and Beakley, 1954).

Convection.

Heat is transferred between a surface and a liquid or a gas by a process known as convection. For the purpose of this discussion we are concerned with the transfer between a surface (e.g. the animal body) and the neighbouring air.

In the case when the surface is at a temperature above that of air, heat is transferred from the surface to the adjacent air by the process of conduction in the same way that the heat is transported through a piece of metal. Then, even in otherwise still air, air currents are caused by the gravitational effects due to differences in density. These natural convection currents, as they are called, cause the heat transfer from the surface to be much greater than it would be merely by conduction in a perfectly still atmosphere. The rate of heat transfer by natural convection depends on the difference between the temperature of the surface and that of the neighbouring air.

Completely still air is rarely encountered. Even in a closed compartment variations in the temperature of the walls and other surfaces set up air currents, so that there is some movement; while when fans are employed or when there are openings to the external air, the air movement may be considerable. When these distinct air currents exist, the heat transfer by convection is increased. The speed of the air currents, as well as the temperature difference, affects the convection transfer.

The equation given for heat dissipation by convection is as follows (Findlay and Beakley, 1954).

$$C = kA\,v\,(t_1 - t_2)$$

where - - - C = convection rate.
A = the surface area.
v = velocity of the air.
t_1 = temperature of the body surface.
t_2 = temperature of the environment.
k = convection conductance.

Conduction.

Hardy (1949) defines conduction as the flow of heat through a medium without the physical transfer of material. Loss of heat is therefore by actual physical contact of surfaces, e.g. when the pig lies on a concrete floor that has water poured on it. Losses by conduction depend of the nature of the surface, since coverings such as hair or wool impede conduction by their insulating properties and by slowing down air movement over the surface.

Vaporization of water from skin and lungs.

According to Dukes (1947) about 25% of the heat produced in resting mammals is lost by vaporization of water from the skin and respiratory passages. The water so eliminated is an insensible loss, and it appears to be about as important in heat regulation in animals whose sweat mechanism is poorly developed (cow and pig) as in animals with a well-developed sweat apparatus (man, horse). At high temperatures, however, the loss of heat by vaporization of water from the skin is much more efficient in animals with a well-developed system of sweat glands. Dogs, more than other domesticated animals, have developed the ability to vaporize a large amount of water from the respiratory passages. When external temperature is high, these animals show heat polypnea, which causes vaporization of much water but which ordinarily causes little change in the gaseous composition of the blood. At times, however, there may be a marked reduction in the carbondioxide content of the arterial blood.

The insensible water loss, cutaneous and pulmonary, under basal conditions is rather constant. However, if the skin temperature is increased, either by external heat or by an increased flow of blood through the skin, there will be an increase in the cutaneous insensible water loss, probably by diffusion through the outer layers of the epidermis. In animals that develop heat polypnea the pulmonary water loss increases with the environmental temperature and is under the control of the respiratory nervous apparatus.

Sweat glands and sweating.

Among the domestic animals sweat glands are best developed and most numerous in the horse, which animal sweats, as does man, from the general body surface. In some species, active sweat glands are confined to certain skin area, and in still others, sweating does not occur at all.

Montagna (1956) gives an extremely detailed account of sweat glands. Here only a very general description will be made. Cattle and pigs have been shown to possess sweat glands of the apocrine nature (Findlay and Beakley, 1954), Hafez and Shafei, 1954).

Reports suggest that these glands are either compound or tubular or simple tubular glands. The secretory portion of each gland is compactly coiled and adjacent loops may be joined by shunts or they may terminate in blind sacs. The deepest portions of the secretory coils extend to the lower part of the dermis and into subcutaneous fat. These glands are partly functional in cattle but non-functional in the pig.

In the sweating species, at times water is poured out on the surface of the skin at a faster rate than it can be removed by evaporation, whereupon visible droplets termed sweat, collect.

The secretion of sweat is under the control of secretory nerve fibres, which leave the spinal cord to form the sympathetic system. According to Dukes (1947) electrical stimulation of the peripheral end of the sciatic nerve in cat or dog brings about secretions of sweat thus confirming that sweating is influenced by secretory nerve fibres. Stimulation causes visible droplets of sweat to appear on the foot pad. That such a production of sweat is not caused by an increase in the blood supply but by the action of secretory nerves is shown by the fact that the secretion can occur after the blood supply to the limb is completely shut off.

The skin is a sensory structure placed between the organism and its environment, bringing the former into relationship with the latter. This function is performed by receptors of touch, warmth, cold, and pain in the epidermis and dermis. When the environmental temperature is high and causes the skin temperature to rise the sensory receptors on the skin structure cause sweat glands to function in the sweating species. The evaporation of sweat from the surface of the skin aids in heat loss. Changes in blood flow through the skin influence heat elimination, dilation of the blood vessels of the corium increases the amount of heat lost, while vasoconstriction has the opposite effect.

(c) Neuro-endocrinological control of Thermal Exchange.

Lee and Phillips (1948) in their review mention groups of nerve cells in the hypotholamic portion of the fore-brain which they call "heat regulating centre", since they exercise a marked and deliberate control over various physiological processes which affect heat loss from the animal body (e.g. respiratory activity, cutaneous blood flow, sweating). They also control heat production (shivering). These centres are extremely sensitive to changes in the temperature of the blood passing through them and it is probably that they are also affected by nervous impulses coming up from nerve endings at or near the surface of the body which are sensitive to temperature change. It is not quite clear how much of the stimulation of the heat regulating centres is mediated through the blood stream and how much through the sensory nerves, but the result is much the same.

In addition to its primary participation in heat regulation, the nervous system is secondarily involved in many ways. Under hot conditions, there is a possible reduction of blood supply to the top parts of the body and the sensitivity of the nervous tissue to lack of oxygen. What is thought to happen is this. Under hot conditions, cutaneous vaso-dilation may greatly increase the capacity of the circulation; liquids tend to pass more easily from the blood into the tissues through dilated capillaries, especially in dependent parts; some water is lost by evaporation from the respiratory tract and also from the skin in sweating animals. Constriction of visceral blood vessels may effect some compensation, but at the expense of the fisceral functions. For moderate stress, the water stores, tegether with reduced urine volume, can effect compensation, but this is limited, so that the increase in blood volume required to match the increased capacity may not be realized. Any fall in the volume/capacity ratio below unity must lead to insufficient blood supply, and this will be most evident in the top part of the body; while the tissues most sensitive to lack of oxygen will show the greatest effect. In some animals brain tissues qualify on both counts.

A good deal of evidence suggests that the anterior pituitary, the adrenal medulla, the thyroid and the adrenal cortex are involved in reaction to thermal stress, but the mechanism and exact inter-relationship are still obscure.

2. Indicies of Animal's Reaction to Thermal Environment.

(a) Rectal Temperature.

Considerable volume of literature has been published on the effect of environmental temperature on the rectal temperature in our domestic animals, both in the field and laboratory - especially that of cattle. Most of the homeotherms show a fairly stable rectal temperature and it only begins to rise when a state of hypothermy exists. The abnormally high rectal temperature may indicate inefficient thermolysis.

Davidson (1948) states "the deficiency of sweat glands mean that the pig has an inefficient heat regulating mechanism".

The normal rectal temperature of the pig is by no means so stable as that of other warm-blooded animals, although it is accepted as 102.6°F. (Dukes, 1947) with some deviation due to age, level of nutrition, muscular activity, reproductive state and condition.

Deighton (1935) cites Terg who gives the limits of normal variation for adult hogs as 101.3°F. - 104°F. while his own observation showed an apparently greater range than those of former observers, viz. - from 98.0°F to 104.8°F. for all adult pigs. He gives average normal rectal temperature as 101.7°F. and considers 102.6°F. for adults, which up to then regarded as normal, too high. He further states that 101.7°F. is suitable for the adult pig in the sty, unless the pig has been exerting itself for sometime, it seemed hardly likely that such a figure as 102.6°F. would be attained.

Davidson (1948) quotes observations by Miller of 100.9°F. - 104.9°F. as the normal variation within which the adult pig need not be regarded as ill and for ordinary practical purposes he gives 103.5°F. as the normal temperature of the pig. Kinsley (1921) also cited in Davidson , says that the normal temperature of a mature pig is about 102.0°F. and of young pigs from 102°F. - 104°F., while Marshall and Holnan (1945) give it as 103°F for all pigs. Smith (1921) quotes Hobday, giving the temperature of the rectum of the adult pig ranging from 100°F. - 102°F., of the young pig from 101.5°F - 105.5°F.

Findlay (1950) in his review gives a range of rectal temperature for all pigs from 98.3°F. to 104°F.

Robinson and Lee (1941) observed in their studies of three 130 lbs. male Berkshire pigs that with the lowest air temperature (75°F.) the rectal temperature at first decreased but later as the time of exposure progressed it rose a little. Further, it was reported that when the air temperature was in the range of 80°F. - 90°F., the rectal temperature increased gradually with time of exposure and tended after some hours to approach an equilibrium, but at a higher temperature the rectal temperature rose rapidly and showed no signs of approaching an equilibrium value. The pigs were able to withstand temperatures from 75°F. - 90°F. for seven hours, but at 65% relative humidity, they withstood 95°F. 100°F. and 110°F., only for approximately 5, 3¾, 2¾, 2½ and 2 hours respectively.

Assessing then, the relative effects of temperature and humidity on the rectal temperature of the pig, Robinson and Lee concluded that below a dry bulb temperature of 85°F., neither temperature nor humidity had any regular well-defined effects on rectal temperature. In fact humidity had little effect until temperatures of 95°F. were reached. At that figure and above it, the higher the temperature the greater was the effect of humidity.

Heitman and Hughes (1949) in their psychrometric chamber studies with pigs over seven day periods and with air temperatures ranging from 40°F. - 115°F., showed that the rectal temperatures of the pigs also increased, the magnitude of the increase being greater the heavier the pig. This study confirms Robinson and Lee's work in that only at temperatures approaching 95°F. could the effect of humidity on rectal temperature be shown. An increase of 2.5°F. was recorded in their rectal temperature when at 96°F. the relative humidity was gradually increased during exposure from 30% to 94%. When relative humidity was gradually decreased to 18% rectal temperature returned to their initial values.

These same authors (Robinson and Lee and Heitman and Hughes) have shown the profound cooling effect of water evaporation. For example, at a room temperature of 100°F., 240 lb. hogs showed rectal temperature of 106.8°F. When four litres of water were poured on the floor, the hogs immediately rolled on the wet surface and within twenty minutes, the rectal temperature was lowered by 1°F. and in ninety minutes by 2°F. Increasing air movement in the chamber still further reduced their rectal temperature, though this air flow movement did not produce the same effect on the dry floor.

Observations on behaviour studies of pigs showed that at high air temperatures (above 80°F.) the animals became lazy and lay on its side on the floor. When the pigs urinated or a wallow provided, others would roll and turn over from time to time to expose their wet sides. Hosing or sousing had a great cooling effect provided atmosphere was not too humid.

Studies on the effect of summer environments on the body temperature of pigs have been reported by Tidwell and Fletcher (1951). These workers exposed eight pigs (with initial weights ranging from 116 to 183 pounds and including two breeds) for 15 minutes to sunlight at an air temperature of 88°F. and another lot exposed to same air temperature but deprived of sunlight - the difference in the rectal temperature between the two groups was 0.3°F., the sunlight exposed pigs recording higher temperatures.

Most of the data from the United States and Australia concerning environmental temperature effects upon pigs have involved high air temperature studies. On the other hand, studies in Europe and the United Kingdom have been mainly concerned with cold fluctuating temperatures and as such a great deal of emphasis has been placed on the subject of providing some kind of artificial heating. Insulation housing is becoming popular with pig breeders.

Heitman and Hughes (1949) showed that pigs tended to lie side by side i.e. to huddle or practice "community heating" when temperatures fell below 60°F. Shanks (1942) found that sudden drops in temperature caused huddling, fighting and savaging. The writer does not specify the exact temperatures involved when such effects are produced, but mention is made of the unhealthy condition of the pig and that the temperature on the farm varied from 68°F. to 44°F in twenty-four hours.

McLagan and Thompsom (1950) and Lucas and Thompsom (1952) and Gill and Thompsom (1956) have all reported similar results on performance of baby pigs to cold environments but have not specified exact temperatures involved when detrimental effects were produced.

(b) Cardiorespiratory activities.

(i) Respiration rate.

Physiological factors known to influence respiratory rates include excitement, muscular exercise, altitude, age, six, size, degree of fill of digestive tract (especially the rumen), sleep and various pathological conditions within each domestic species.

Dukes (1947) and Wirth (1956) indicated the normal respiratory rate per minute of the adult pig at rest to be 8 - 18.

The effect of thermal environment on the respiration rate has been widely investigated in the field and laboratory in cattle, but to a lesser extent in pigs. Under the influence of excessive heat burdens, pigs exhibit polypnoea to a degree which depends on the magnitude and duration of the heat stress to which they are exposed. Robinson and Lee (1941) have shown the effect of time of exposure to different air temperature at a constant humidity of 65% R.H. on the respiration rate of three 130 lbs. male Berkshire pigs. These workers have shown that -

(i) A gradual increase in respiration rate occurred on exposure to 75°F. to 80°F. whereas at 85°F. and beyond, the increase was almost precipitous.

(ii) After two hours at 80°F. the respiration rate was not even doubled but at 85°F., 90°F. and 95°F., there was almost four-fold increase and at 110°F. the increase in two hours was about nine-fold.

The respiration rate grid (Table 1) reproduced from Robinson and Lee's work, it will be seen that whereas the pig could tolerate temperatures from 75°F. to 90°F. for seven hours, it could only tolerate 95°F., 100°F., 105°F. and 110°F. for periods of 5½, 4, 3 and 2½ hours respectively. At 110°F. the respiration rate reached the

T A B L E   I.

Respiratory Rate Grid.

Relative Humidity %	DRY BULB TEMPERATURE °F.								
	70	75	80	85	90	95	100	105	110
95	38	25	57	70	104	[165]			
85	40	36	65	69	70	[193]	[210]		
75	40	41	34	21	141	197	[236]	[432]	
65		50	52	110	139	[194]	[295]	[392]	[417]
55			40	182	137	140	197	[298]	[345]
45				138	127	115	140	[228]	[162]
35						81	177	[172]	[189]
25								[183]	[140]

The figures in each square represent the average respiratory rate per minute during the time the pig was exposed to a particular atmospheric condition. Figures in square brackets indicate that animals had to be removed with the rectal temperature of 107°F. before seven hours had elapsed (Reproduced from Robinson and Lee, 1941.)

astonishing figure of 280 beats per minute after only 2½ hours of exposure. These workers further report that above temperatures of 95°F. reductions in the humidity of the room tended to reduce the respiration rate;and changes in the respiratory rate preceded rises in rectal temperature while panting occurred at rectal temperatures of the order of 103°F. Similar work has been reported by Heitman and Hughes (1949) for pigs weighing 166 to 260 lb. liveweight.

Tidwell and Fletcher (1951) have shown that respiration rate increased with increasing air temperatures. They reported differences between breeds in respiration rate rise when exposed to summer sunlight for fifteen minutes. The two breeds used were Duroc Jerseys and Poland China. The latter showed 25.2 respirations greater than the average respiration rate rise for Durocs.

Very little has been reported about the effects of low temperatures on the respiration rates of the pig. However, several workers have indicated that respiration rate decreased in dairy cattle as ambient temperature decreased. On the other hand, Findlay and Beakley state without reference to experimental work that temperatures down to 0°F. have little or no effect on the respiration rate of cattle.

(ii) Pulse rate.

Pulse rate of the pig, like any other animal is subject to wide variations and factors other than temperature, humidity, etc., are involved. Wirth (1936) indicated the range of normal rate per minute of mature pig at rest to be 60-90.

In cattle, Blaxter (1943) found a difference in pulse rate when the steer was lying and standing. Brody (1945) states that the increase in pulse rate on standing was 3% for a heavy steer. Kelly and Rupel (1937) showed that pulse rates varied from 60 beats per minute when animals were at rest, to as high as 96 beats per minute when they were feeding.

With regard to pig, evidence in the pulse rate is conflicting. According to Robinson and Lee (1941) the pulse rate tends to rise with rectal temperature during exposure to heat while Heitman and Hughes (1949) claim that the pulse rate decreases with increase in environmental temperature.

As has been stated above these effects are bound up with changes in heat production and food consumption etc., and it is difficult to be related to environmental temperature.

(c) Skin Temperature.

Under shade conditions when the animal is not at stress, the temperature of the skin surface is a few degrees below the interior of the body temperature, the extent of the difference depending upon the temperature of the environment. However, when the radiant energy having the intensity of sunlight impinges upon the skin surface this situation may be completely reversed.

The skin temperature is essentially a result of heat production and heat loss. These two factors may be influenced by wide ranges in environmental temperatures as has been shown by Biomerschmid (1943a) - the difference in heat production in the body of a 1000 lb. bull on a mixed ration and the heat absorbed on the surface of its body from solar radiation is in the vicinity of some 11,000 Calories. Heat production by the animal would of course depend on the amount of foot eaten but there is no doubt that the heat load resulting from solar radiation can be very high.

Missouri workers (1953 and 1954) working with cattle report on the relation of skin and hair temperature have shown that an increase in air temperature caused an increase in skin temperature and that a large gradient existed from skin surface to the tip of the hairs. They further showed that the gradient disappeared at temperatures of 100°F. and 105°F. and that skin temperature varied from region to region over the body surface. This latter result has been confirmed by other workers, Klem and Lee (1955) and Findlay and Beakley (1954).

The pig's skin is in a considerably worse position since it has little protective coat and therefore most of the radiation will be directly absorbed. It has often been reported, where the intensity of solar radiation is high that marked edema, desquamation, erythema and itching occurs, especially where the skin is thin, as behind the ears and the udder of the sow (Davidson, 1946). Such a condition is caused by the direct injury to the cells of the epidermis by ultra-violet radiation.

The amount of solar radiation that is absorbed by the coat of an animal is determined to some extent by the colour of the coat. About half the energy in the solar spectrum is in the visible portion. The proportion of this, which is absorbed on the coat of the animal, can be gauged roughly by the colour of the coat. A white surface may absorb up to 100% (Findlay and Beakley, 1954).

Colour of the skin is therefore an important factor as regards the effect of solar radiation on the skin of the pig. The colour of skin of the pig is either white or dark in contrast to the colour of the coat.

Blum (1945) states that dark skin is less sensitive to sunburn and to cancer of skin than is the light coloured animals and that it is probably that the presence of considerably melanin pigment distributed through the epidermis is an important factor in determining both. Bonsma (1948) states that the dark skin is better adapted to life in tropics because the pigment protects it against ultra-violet irradiation. The major portion of the sunlight is absorbed before it has penetrated more than a few millimeters. The radiation is scattered in all directions before it has penetrated far into the corneum, due to the tiny flake-like cells or elements composing this layer, which represents the remains of the dead epidermal cells.

Observations made by Guillaume (1926) Lovisata (1929) and Miescher (1930) and cited in Blum (1945, showed that thickening of the corneum as a result of the epidermal hyperplasia brought about by the action of ultra-violet radiation caused the skin to become less sensitive to sunburn. However, evidence is mounting in favour of pigment in the skin to be the substance which gives protection against the ingress of heat. The pigment is deposited largely in the basal cells of the epidermis of white skinned animals while some of it migrates into the superficial layers. One property, according to Blum (1945), of melanin is that it absorbs the 'burning' property of the sun and acts as an "internal filter". In dark-skinned animals the pigment is much more uniformly distributed throughout the epidermis than in the skin of white animals.

Findlay and Beakly (1954) pointed out that the solar radiation falling on the black surface may absorb up to 100% of visible radiation which means that the dark skinned animal is actually at a disadvantage. This additional heat the dark animal must get rid of by evaporation which means it must drink more water and produce more sweat under like conditions of exposure than must the white-skinned animal. It has been suggested that the pigment of the skin on dark (as well as white-skinned animals to a small extent) serves to raise the surface temperature when exposed to sunlight and to increase sweating which in turn helps to cool the surface. With regard to pig however, applicability of this hypothesis is not clear.

(d) Blood composition.

Reports by Findlay (1950), Rusoff, Frye and Scott (1951) and Blencoe and Brody (1951) have all shown that certain changes are brought about in the blood composition of farm animals as a result of the change of environmental temperatures. Indications are that high haemoglobin values are associated with high adaptability to extreme conditions of temperature. Specific gravity, the Ca:P ratio and the number of erythrocytes have also been shown to rise with increased air temperature. Blincoe and Brody (1951) in their studies with cattle have shown that obvious changes in blood composition occur when temperatures above 65°F. is reached. Creatinine levels increased and the reduction of ascorbic acid and cholestrol levels. They further reported that such changes in the blood composition are the result of reduced feed intake.

Findlay and Beakley (1954) in their studies with Ayrshire calves have shown that high environmental temperature caused blood dilution and cold environmental temperatures caused blood concentration. Similar response to moderately high temperatures have been obtained with dogs.

Data on the effect of high temperatures on the blood composition of pigs is scanty. Newland, McMillan and Reineke (1952) in their study on temperature adaptation in the baby pig have reported that in baby pigs chilled at 34°F., there is a significant drop in the blood haematocrit values, though with pigs ten days old or more chilling caused almost no change in all concentration. These facts indicate that the young pigs increase the water content of their blood and thereby cause a decrease in their cell concentration.

See Table 2. - adapted from Newland *et al.*

Table 2.

Blood response in pigs exposed to chilling changes in Blood Haematocrit (cell volume) in pigs of various ages.

Age in days.	No. of pigs.	Av. haematocrit %		Body temperature.	
		Before chilling.	After chilling.	Before chilling.	After chilling.
2-4 d-olds	15	33.6	26.8	102.0	99.2
10-12 d-olds	6	30.2	30.8	102.8	101.8
23-27 d-olds	9	28.7	27.6	102.8	101.7

In older pigs there is no shift in water concentration in either direction. The blood dilution in the young pig takes the reverse course of animals with a normal functioning temperature regulating mechanism. Since older pigs show no change in their blood haematocrit it would appear that the development of the temperature regulating mechanism in young pig is retarded. Howie et al.(1948) suggests that the temperature regulating mechanism in pigs is not fully developed even at 8 weeks of age.

Newland et al. has also shown that chilling one day old pig causes an increase to occur in its blood sugar. Increase in blood sugar is apparently a defence mechanism of the body against cold. They also showed that pigs fasted 8 hours before chilling showed less glucose increase than those fasted 3 and 5 hours.

(e) Plane of nutrition.

As early as 1923, Benedict and Ritzman showed that the plane of nutrition affects the skin temperature of steers in that within certain limits skin temperature increases as the plane of nutrition improves (Findlay and Beakley, 1954). When the atmospheric temperature is high then the animal with a high skin temperature is at a disadvantage i.e. it will be at stress.

Robinson and Lee (1941) studied the effect of the nutritional plane upon the reactions of the animals to heat. They found that in the pig, like all animals, the reaction of the high plane animals to hot conditions (D.B.85°F.; W.B. 85°F.) were significantly higher than those of low plane animals. The reaction was much more pronounced under hot-dry conditions (D.B.106°F.; W.B.86°F.) The behaviour of the rectal temperature, pulse rate, respiration rate and weight loss were all measured. It was shown that the high-plane diet animal had significantly higher rectal temperatures, respiratory rates, and lost weight compared to animals on low-plane diets. Pulse rate rises were not as marked.

There is a general belief that fat animals do not do particularly well under tropical conditions. On this assumption Robinson and Lee studied the effect of the differences in the proportions of protein in iso-calorie, adequate diets. Here the animals were fed successively upon different diets which were of equal calorie value but contained proportions of protein varying from 5 to 28.5 per cent. The animals were fed for a week with a particular diet and were at the same time exposed to a critically hot atmosphere for seven hours and their reactions studied. Evidence obtained thus showed that a high proportion of protein had no marked significant effect upon the reactions of the animals to heat.

Nevertheless Mitchell and Edman (1949) in a review of nutrition in a hot climate say that in the case of humans there is some suggestion that protein requirements may be slightly raised, due to an increase in the endogenous catabolism of body proteins which is revealed by an increased output of creatinine, and a loss of nitrogen in sweating. It is therefore of some interest that Brody (1949) reports that the creatinine level in the blood of dairy cows rises steeply with rising ambient temperatures.

It is possible that there is an increase in the requirements fo certain minerals in the tropics. Mitchell and Edman (1949) report that there are indications that the human requirements of thiamine and ascorbic acid may rise in the tropics as do the requirements of salt, calcium and iron.

According to Lee and Phillips (1948) with the oxygen lack in the visceral region it would be the motor functions which would be affected more than the secretory and it is largely with motor functions that appetite is associated. Appetite is reduced at high temperatures and Patchell (1951) quotes Brobeck who suggested how appetite is reduced at high temperatures in rats, and that food intake is a regulator of body temperature since it is depressed in the heat and increased in the cold. Loss of appetite as a result of heat would mean less food intake which further means less internal heat production so that so much less heat would have to be lost. We know that animal, in order to maintain homothermic condition must be provided with foodstuff. If appetite is lost then food reserves in the body will be used to carry on essential body processes with the result that growth, fertility, lactation etc. will be markedly affected.

Under cold conditions the appetite is stimulated. The mechanism for this is not clear. According to Lee and Phillips (1948), it may well be the result of stimulation to the adrenal medulla from the hypothalamus, if not from the heat-regulating centres themselves. Adrenalin is known to increase hunger contractions under certain conditions. Increased appetite according to Patchell (1951) under cold conditions does not necessarily mean increased production; on the contrary, production may decrease as more nutrients are needed to provide fuel for increased metabolism and the increased heat loss.

(f) Production activities.

Reviews on production activities of our livestock have received a great deal of attention in recent years. Most of the work has been reported on cattle by Brody and Associates (1948) and Ritzman and Benedict (1938).

Production activities in this study will include (i) Lactation and (ii) Growth.

We have seen under the section on plane of feeding that increasing temperatures depress appetite, food consumption and consequently reduce heat production. As a result of the decrease in food consumption productivity is affected.

(i) Lactation: - In all livestock and especially in cows, adverse changes occur in the yield and composition of the milk with rises in air temperature. In a review by Findlay (1950) it was shown that at environmental temperatures between 70°F. and 80°F. milk yield in cattle of temperate breeds were not significantly affected but that the fat % of the milk was reduced. Above 80°F., milk yield decreased and fat % showed a rise - milk yield in Holstein cows showed a decrease by 50 to 75%. For Jerseys and Brown Swiss cows the temperature that caused a sharp drop in milk production was 85°F. (Brody1945, 1948).

The same authors showed that the cold environment increased appetite and food consumption but this did not necessarily mean higher production. A higher metabolic rate as a result of higher intake was required for increased heat production to keep the animal in condition - production was again affected. It was shown that Holstein, although at temperatures of 5°F. was little affected with regard to milk production, Jerseys were found to be markedly affected even at 32°F. In both the cases the animals had to eat large amounts of feed to keep themselves in condition for this high production.

(ii) Growth:- In recent years numerous experiments have been carried out to study the weight gains of pigs, sheep, cattle and other livestock under low and high temperatures. Psychrometric chamber studies as well as field observations have been made.

Psychrometric chamber studies.

Californian workers, Heitman and Hughes (1949, 1958) in their psychrometric chember studies have shown the effect of high temperatures on liveweight gains. They showed that at 90°F. gains of less than one pound were observed at all liveweights of 200 lbs. or more. At 100°F. all weights over 100 lb. gained only 0.39 lb. per day and at 110°F. even 100 lb. pigs lost considerable weight. Similar reports have been made by Warwick (1958).

Controlled low environmental temperature studies have not been made but it has been shown by Heitman and Hughes (1958) that even at 40°F., 350 lb. hogs lost weight whereas at 55°F. they gained 2.41 lbs. per day.

That the growth of baby pigs is affected has been shown by Davidson (1948).

Field studies.

Trials conducted at Georgia Experimental Station, Tifton (1957) showed the advantage gained from a cooling device for pigs during hot weather. Data cover two years. In 1954, fattening pigs with access to a sprinkler system gained 1.63 pounds per day compared with 1.31 pounds per day in non-sprinkled. Mean and maximum temperatures were 72°F. and 96°F. respectively. In 1955, the fattening pigs with access to a sprinkler gained an average of 1.54 pounds per day. The mean temperature was 71°F. with a range of 85°F - 89°F. with mean minimum at 72°F. and a range of 64°F. to 74°F.

The gain in th e two years' experiment was 12% more for hogs which had access to a simple form of a sprinkler.

Minnesota Experiments (1957) cite Oklahoma experiments to point out that sows and gilts protected from summer heat by a cooling system produced 2.35 more live pigs per litter than a similar group with access to open shade, but without the spray. Sows with spray averaged 10.06 live pigs compared with 7.71 for the others. No mention of temperature was made.

Cold temperature studies have been made but due to respiratory troubles encountered in these tests, no direct comparable measurements were available. However, suffice it is to say that lower environmental temperatures (below 45°F.) have serious repercussions leading to uneconomic gains in fattening pigs and unhealthy condition in the breeding animals.

3. Techniques of Measurement.

Numerous instruments have been devised by experts for the measurement of body temperature, respiration rate, pulse rate and skin temperature. These instruments are of many descriptions and vary considerably. Some of these instruments are very complicated structures so that only the simplest forms will be discussed in this section.

With regard to techniques of measurement - which differ from instrument structure - we are confronted with several problems. When working with livestock, we are working with animals that do not understand our work and naturally they provide resistance. The animals are disturbed physiologically and psychologically so that the taking of measurements may intorduce errors of great magnitude. It is therefore of great importance that study of this nature be made on animals that have been trained for some time prior to actual experimentation. It is also of importance that the animals be handled as gently as possible for studies of this nature.

(a) Body temperature.

With livestock body temperature is always taken in the rectum. The rectal temperature is a fairly reliable index to the deep body temperature, especially under warm conditions, so that any departure from the 'normal' range should be noted. It is one of the most significant of animal reactions to heat stress.

The most common instrument used to measure the rectal temperature is the clinical thermometer. According to Lee (1953) the heavy veterinary pattern is preferable to the medical, since it is of higher graduation and long enough for animal work.

Clinical thermometers vary a great deal one from the other in accuracy and in an experiment it wouldbe best that the same one is used. New thermometers should always be tested for accuracy by immersing them together in a pot of water at each of these temperatures over the range 35-43°C. If a thermometer which is known to be accurate such as a previously standardized laboratory thermometer, can be included, the check is even more satisfactory. Precautions are therefore necessary.

1) According to Lee (1953) thermometer should always be inserted well into the rectum e.g. 9-10 c.m. in depth. Yaglow (1949) quotes Kitching's experiment to say that he recommends 8 c.m. which agree well with those of the stomach and of the urine voided during tests in subjects who are in thermal equilibrium with the environment. Kriss (1921), quoted by Patchell (1950), found a temperature gradient in rectal temperature in dry cows. The deeper the insertion, the higher the rectal temperature. He used 4", 5", 6" and 7". At 4", the reading was 0.8°F. lower than at 6 to 7 inches. Other workers Regan and Richardson (1938) used 5", Seath and Miller (1946) 3" and Bonsona, 3" (1949)

From the above observations it becomes necessary that the same thermometer be used at the same depth of insertion at each reading in an experiment since the research worker is more concerned with differences rather than actual precise determinations (Patchell, 1951). In order to facilitate the same depth, Patchett used a rubber bung at the end of the thermometer.

2.) Lee (1953) recommends three minutes to be ample for the thermometer to take up the rectal temperature of the rectal walls. It has been reported that the longer the thermometer is in the rectum, the higher the reading. Here again we are concerned with the difference rather than actual precise determination so that three minute reading at each time is satisfactory.

3.) Before insertion, the thermometer must always be 'reduced'. This is necessary where the air temperature is higher than the rectal temperature. The thermometer can be 'reduced' by shaking it or dipping in cool water. Dipping in water also serves as a lubricant and insertion in the rectum is easily manipulated. Workers use vaseline or even oil but their use is questionable.

4.) When the thermometer is removed from the rectum it should be read immediately. Cotton wool is often used to wipe the fecal matter from the thermometer surface. When reading, the thermometer is held horizontally and shaded by the observer's body, and immediately recorded.

5.) Whether the fecal matter in the bowel affects reading is not clear. According to Kriss (1921) it had no effect, while Hancock, quoted by Patchell (1951) says it does.

6.) Precautions must be taken against the position in which the animal is at the time of taking the rectal temperature. Brody (1945) has shown that the heat production of the standing animal is higher than one lying; it follows that the rectal temperature in the standing animal would be higher.

7.) Kriss (1921) reports that drinking water causes a decrease in rectal temperature but after 2-3 hours the temperature returns to normal. Robinson and Lee (1941) report that the pig's rectal temperature was definitely reduced by giving water equivalent to half of that lost by evaporation but it was not further reduced by increasing the water supply to full replacement. It would appear then, taking such measurements, animals should not be watered during the experiment.

8.) MacDonald and Bell (1958) quote Kelly and Rupel, and Kriss, report that in cows eating, caused a slight increase in rectal temperature. Benedict and Ritzman (1938) found that plane of nutrition had no effect. Hutchinson and Mabon (1954) observed low rectal temperature in the mornings reflected inadequate nutritional level to maintain body temperature, as they were significantly increased by a moderate supplementary ration.

9.) According to Newburgh (1949) glass thermometers do not conform to curvature of the rectum, and may therefore introduce errors due to poor contact and lag. He recommends that a ten minute lag period of observation is desirable in hot and cold climates.

Thermocouples and a potentiometer are recommended but Lee (1953) finds the accuracy obtained in measuring rectal temperature with a good standard thermometer is as good as by any other means.

(b) Respiratory rate and respiratory volume.

Two methods are available for measurement of respiratory rate. This measurement is perhaps the simplest of all the four measurements viz., rectal temperature, skin temperature, pulse and respiration rates.

This measurement can be made from a distance. Respiration rate is the average number of complete respirations made per minute under the given circumstances. Movement of some part of the body accompanying each respiration is picked out and a total number of movements counted over a suitable period. Flank movement is the commonest measurement.

Counts should extend 2 minutes (Lee, 1953) but for practical purposes half-minute readings are equally good. Counts should be repeated until 3 counts at least agree or are close. When the animal is respiring very fast, actual counting is impossible. In this case an approximation may be obtained by establishing a rhythm against time, e.g. 20 in ½ minute. This can be converted to respirations per minute. Patchell (1951) suggests a tally counter in one hand. A watch should always be handy but a stop watch is better.

Patchell (1951) describes a method whereby a hand is placed in front of the nostril and counting the exhalations. This method, he suggests works well with only quiet animals.

Lee (1953) suggests a method where respiration counts by listening to breath sounds through a stethescope. This method again could disturb the animal if it is not accustomed to the observer.

When respiratory measurements are taken it is desirable that animals are handled quietly and further more all experimental animals are measured under the same conditions i.e. if an animal is grazing in the paddock and another standing in the shade then the two animals will have a wide variation in their rates.

Findlay (1950) mentions a third method used with intact animal. His method involves the insertion of thermocouples or thermistors in the nostrils. The thermistors or thermocouples are held on a light expanding spring in the middle of the nostril. If the temperature of the environmental air is different from that of the exhaled air, the respirations may be displayed as fluctuations in the temperature of the thermocouple or thermistors. Thermistors are preferred for this method because with them the effect of the temperature change can be more readily amplified. Any suitable recording galvanometer will display not only the rate, but the amplitude of the respirations.

Dukes (1947) suggests a method in the intact animal whereby a tube is connected to a side-arm of a tracheal cannula and then to a tambour or some other form of a recorder. Inspiration results in a decrease of the pressure in the tube and recorder, causing a downward movement of the writing lever; expiration elevates the pressure in the tube and recorder, causing an upward movement of the writing point.

Another suitable method for intact animal is the use of pneumograph or a stethograph of which several forms are obtainable. This is tied to the animal around the thorax in an appropriate location and then connected to the recorder. Inspiration increases the capacity of the pneumograph and writing lever moves downwards; expiration causes the opposite effect. Further details are given in Dukes.

Numerous methods of measuring the non-intact animal are given by Dukes.

(c) Respiratory function.

Findlay (1950) defines respiratory minute volume as the volume in litres of air breathed by the animal per minute and the tidal air is the volume of air expired by the animal.

Respiratory function is desirable for the study in environmental physiology but under field experiments, however, it is not altogether possible. Only when the animal is stanchioned can such measurement be made possible.

No attempt will be made to detail respiratory function studies here. Only the general principles involved in the techniques employed will be mentioned.

The various devices which are used in these methods are referred to as respiration apparatus. Three conventional methods of collecting data of this type are mentioned.

(a) The animal is made to wear a mask with a dry gasometer which provides for the analysis of the inspired and expired air.

(b) The closed-circuit type - its name derives from the fact that the same air is continuously circulated, with provision for the removal of the waste products and the addition of oxygen. Here CO_2 and water are removed from the outgoing current by absorbents. Their output is determined by recording the increase in weight of the absorbing vessels. The oxygen of the circulating air is renewed through a meter by means of which the volume added is recorded. The residual air at the conclusion of the experiment is analysed to take account of any changes in composition from that of the start. For this close-circuit type, construction of an air-tight unit in which the temperature and humidity are well-defined is essential. Construction of such a unit is expensive and the larger the animal the greater the cost.

(c) The open-circuit type differs from the one just described in that the circulating air is drawn from the atmosphere, and the outgoing air or a measured fraction of it, is passed through absorbents.

In either the closed and open-circuit types described gases other than the pulmonary exchange are also introduced such as intestinal gases and perspiration. Brody (1930) describes an air-tight muzzle for farm animals when it is not desired to determine the losses in intestinal gases and in perspiration. He eliminates the chamber with its large volume of air. This elimination has certain advantages. Short time observations are accurate and changes are traced sharply.

(d) Heart rate.

There are a few methods that have been devised for satisfactorily recording the pulse rate of our domestic livestock.

There are two common methods employed by the research worker for measuring the pulse. These methods have their limitations.

(a) The pulse may be palpated in many of the superficial arteries, the ones most accessible varying in different species. In cattle the caudal or carotid arteries are commonly palpated. In the pig, the carotid artery is not accessible and according to Dukes (1947) it is difficult or impossible to measure pulse rate by simple palpation. However, the posterior-tibial artery on the medial surface of the tibial region, 4 to 5 inches above the hock is a convenient place for measurement in the pig.

(b) The pulse rate may also be read by using a clinical stethoscope, placed on the lower fore-rib of the standing animal.

For both these methods a stop watch or a wrist watch is required and pulse beat recorded against time-reading over half-a-minute or a minute is taken at intervals and repeated 3 times.

Although the above methods suffer from disadvantages (Findlay, 1950) they are nevertheless reasonably accurate provided the animals are handled quietly. The animals are very sensitive and the touch of stethescope or fingers may upset the animal. Both methods require the presence of an observer in very close proximity to the animal. Also neither of the methods will give a record of the pulse rate over a prolonged period and yet allow free movement to the animal. Physiological factors known to influence heart rate include excitement, muscular exercise, high environmental temperatures, altitude, age, sex, size, digestion, sleep and various pathological conditions within each domestic species.

In field experiments, however, it is probable that manual palpation methods are the only ones that can be used for taking the heart rate.

In psychrometric chamber studies elaborate methods have been used and details of such equipment and techniques are discussed by Findlay (1930) and Lee (1953).

(e) Skin temperature.

'Skin temperature' is a loose term and could either mean what Lee (1953) describes as "coat surface temperature" or "skin surface temperature".

The "coat surface temperature" has been defined as the temperature of the surface that is 'seen' when an observer looks at the animal without disturbing it in contrast to "skin surface temperature" which has been defined as the temperature of the outer layer of epidermal skin cells. This latter surface is the outermost portion of the continuous body structure and represents the place at which the body and environment first come into contact.

In cattle short hair predominates and that it forms a thick set covering over the body. It is this surface which exchanges heat by radiation with its surroundings; it is this surface from which heat exchange and evaporation occurs, so that this so-called "coat surface temperature" is required to be measured.

Pig on the other hand, unlike cattle and sheep are poorly provided with hair so that the radiation of the sun comes directly in contact with the skin. It is this "skin surface temperature" we are concerned with.

Various methods of measurement have been reviewed by Findlay (1950), Patchell (1951), Lee (1953) etc. for cattle.

Clinical Thermometer: Lacking more elaborate apparatus, valuable measurements can be made with a clinical thermometer. Mc Farlane (1958) suggests holding the bulb of the thermometer against the skin. There are obvious errors, since the temperature reached by the bulb is affected by the temperature of the air. Burton (1934) cites Stewart to say that if the bulb was held in a cleft cut in a small cork and the exposed portion held against the skin, the rest of the bulb was insulated effectively and readings would deviate less than 0.5°C. from those obtained by thermocouples or resistance thermometers. This accuracy is sufficient for most clinical investigation. Time must, of course, be left to insure that maximal temperature is attained. However, this method of skin temperature measurement is not widely used.

ii) More elaborate methods are all electrical; two of them are described below.

<u>Thermocouples:</u> Elder (1941)describes in detail this method.

This thermoelectric effect is observed whenever, in an electric circuit composed of two or more metals (or alloys), the different junctions between the metals are at different temperatures. An electromotive force is set up, the magnitude of which depends on the particular metals used, and which is proportional to the difference in temperature between the two junctions, over small temperature ranges. This system of two dissimilar metals is known as a thermocouple. In other words when we have two dissimilar metals forming a circuit and one of the junctions is at freezing point and the other at the temperature of the environment of the skin, an electric current will be set up in proportion to the difference between the temperature of the hot and the cold junctions.

The various metals and alloys can be arranged in a series according to the magnitude of their thermoelectric effect when used together in a thermocouple. Therefore, for maximum sensitivity the metals should be chosen from opposite ends of the thermoelectric series.

Constantan is one alloy widely used for thermocouples because of its general all-round suitability. Constantan is situated near one end (the negative end) of the series. Metals such as copper, iron and alloys such as brass and steel, are situated towards the positive end of the series, and therefore, produce a large thermoelectric effect when used with constantan.

There are many sources of errors in the use of thermocouples and they should be guarded against.

<u>THERMAL CONDUCTIVITY</u>:- Thermocouples should conduct as little heat as possible away from the skin. Metals and alloys vary in their thermal conductivity and those that have low thermal conductivity are preferable. Copper and constantan satisfy this requirement well.

<u>MECHANICAL PROPERTIES</u>:- The wires should be as thin as possible but freely supported, either by their own rigidity, or by being stretched across an open frame. Copper yields too easily under tension but constantan stands up well to continuous handling.

<u>CHEMICAL PROPERTIES</u>:- Repeated use of thermocouples are subject to corrosive action of moisture on the skin. It is therefore recommended that the material should be chemically resistant. For this purpose constantan has been found to be suitable.

<u>Sources of Error in Skin Temperature Measurements.</u>

<u>Physiological reactions</u> - caused by contact, pressure or irritation induced in using the instrument. Findlay (1950) points out

to the possible effects of vasomotor reactions and stimulations or inhibition of the sweat glands or arrector pili muscles. Any of these actions would change the temperature of the skin and give untrue readings. Constant pressure of application is important.

Physical disturbance of the heat exchange between the skin and its surroundings may be caused by the presence of the thermocouple. Conduction of heat away from the junction will alter the temperature of the skin at the junction and may disturb the effect of wind and radiation to which the skin is exposed.

Temperature equilibrium may be difficult to establish between the junction and the skin. Since only one surface of a junction can be in contact with the skin it follows that the other side is exposed to the environment. The error, here again, as in the case of physical disturbance, will be either positive or negative, depending on whether air temperature is hotter or cooler than the skin.

To measure the e.m.f. (electromotive force) developed by the couple, either a direct reading galvanometer, a potentiometer or a recording potentiometer may be used. Galvanometer is the simplest since it gives direct reading of temperature. For a constant voltage the galvanometer reading depends on the resistance of the electrical circuit because it registers current and not voltage and variations in the resistance in the thermocouple or instrument will affect the reading (Patchell, 1951). To make these variations small a large resistance is added to the galvanometer but this reduces the sensitivity of the instrument. However, this is highly satisfactory for ordinary outdoor or indoor use.

The best method to use for measuring the e.m.f. is by means of a potentiometer. Scott (1950) describes the use of a a potentiometer. He states that a current is passed through a wire to cause a uniform voltage drop along the wire; by moving a sliding contact along the wire, any voltage within the range of the instrument can be obtained, the voltage being proportional to the distance the slider is moved. The thermocouple and a galvanometer are connected between the sliding contact and one end of the wire. When the potentiometer voltage equals the thermocouple voltage the galvanometer reads zero and the voltage or temperatures can be read by noting the position of the sliding contact. At the point of balance no current is taken from the thermocouple and for this reason the thermocouple resistance does not affect the readings. The slide wire has to be calibrated periodically by a standard cell, incorporated in the instrument.

The thermocouple is usually some distance from the potentiometer and connecting leads are used to join the two. The cold junction - usually melting ice in a thermos flask - is placed where the lead wires join the thermocouple wires.

The great advantage of thermocouples is the ease with which they can be made, the universality with which they can be applied and the simplicity of the measuring devices that can be used with them. Their disadvantages are the care with which they must be used, the need for frequent recalibration, and the need for a cold junction at a constant accurately known temperature.

(b) Resistance Thermometers:- While resistance thermometers are the best instruments for indicating and recording temperatures with accuracy, the accessory apparatus is expensive and unsuitable for field work. These types consist of an applicator containing an element whose resistance changes with changes in its temperature. It is connected with an apparatus which measures the changes in resistance with accuracy and displays them as changes in temperature.

There are numerous faults as with any instrument but the serious objection that is made against the use of conventional resistance thermometers in taking surface temperatures is the large area which the thermometer covers, so upsetting the nature of the surface whose temperature is required.

(e) Methods of measuring the thermal elements of climate.

If the thermal environment is to be completely specified, the four individual thermal factors - the temperature, humidity and the rate of movement of the air, and the radiation from the surroundings - must all be taken into account. Instrumental measurements of each must be made.

(i) Air Temperature:

The temperature of the air is commonly measured by means of the mercury-in-glass thermometer. A sling or whirling hygrometer is also used for this purpose. With a mercury-in-glass thermometer, it is normally suspended from the instrument stand, so that the air temperature can be read from time to time. However, the disadvantage is that any radiant heat will influence the reading of the mercury-in-glass thermometer and thus cause inaccuracy. On the other hand with sling hygrometer readings, owing to the passage of a rapid current of air over the thermometer bulbs, errors from this source are generally so slight as to be negligible.

The whirling hygrometer is also known as a psychrometer. It consists of a pair of thermometers mounted in a frame which is provided with a handle. By rotating the instrument about the handle, like a rattle, the thermometers can be whirled rapidly so that their bulbs pass through the air at a considerable velocity. The bulb of one of the thermometers is covered with thin muslin and this kept moistened by the wick leading from the water reservoir. Rapid whirling immediately before the thermometers are read is essential. Satisfactory wet-bulb temperatures cannot be obtained by merely suspending the instrument in relatively stagnant air; a strong air current, such as is ensured by the whirling, is absolutely necessary for accuracy. The air velocity, or the velocity of the bulb of the whirled thermometer relative to the air, should be of the order of 600 ft. per minute.

The water supply for the wet-bulb should, if possible, be distilled water. If this cannot be obtained, the water should be the purest procurable at the time. After being used for some time, the muslin covering the bulb may be stiff and non-absorbent, and if such signs appear the muslin should be removed. New muslin should be thoroughly washed before use.

When an observation is to be made, it should first be seen that the wet bulb is indeed wet. The instrument is then whirled as rapidly as possible for 30 or 40 seconds, stopped, and the wet bulb read immediately. The whirling is repeated and the reading checked. If necessary, further repetitions must be made until two successive readings of the wet-bulb temperature agree very closely, thus showing that the minimum temperature of the wet-bulb has been reached. This reading is recorded, the dry-bulb temperature is also read and noted. It is especially important that the wet-bulb temperature be read first, immediately after whirling has ceased. Otherwise the temperature shown by the wet-bulb instrument will tend to rise.

An elementary precaution, but one frequently neglected, is that when the instrument is read, the observer's hands should be kept away from the bulbs and the thermometer stems; and the observer should take care not to breathe on the instrument whilst scrutinizing it.

(ii) Atmospheric relative humidity:

The most widely used method of measuring the humidity of the air is to observe the temperatures of the wet and dry-bulb thermometers, and then from suitable tables, to read off the humidity. The dry bulb thermometer measure the air temperature, and unless the air is completely saturated with water vapour the wet-bulb temperature is below air temperature. The drier the air, the more rapidly is water evaporated from the wet bulb, and the more is that bulb cooled. Hence, at a given air temperature, the difference between the dry and wet-bulb temperatures - sometimes referred to as the depression of the wet-bulb temperature - increases as the humidity of the air diminishes.

(iii) Air movement:

The most common method is by use of a cup anemometer. It is a familiar meteorological instrument consisting of cups mounted vertidally on horizontal arms which rotate with the wind pressure (Lee, 1953, F.A.O. Development Paper No. 38).

(iv) Solar radiation:

A simple and easy method to compute the radiation intensity is from readings of the globe thermometer. The globe thermometer consists of a hollow 6" copper sphere, coated with matt black paint, and containing an ordinary thermometer with its bulb at the centre of the sphere. The temperature of the instrument depends on the environment in which it is placed. If the walls and other surfaces which surround the globe are warmer than the air, the temperature recorded by the thermometer inside the globe will be above air temperature; and conversely, with the surroundings cooler than the air, the globe thermometer temperature will be below air temperature. The globe thermometer reaches approximate equilibrium with its environment after about 20 minutes exposure.

The mean radiation intensity at the point of observation can be expressed as an energy influx, i.e. in terms of B.Th.U./sq. ft./hr.; but studies of the thermal environment, it has become customary to give it as the "mean radiant temperature" or "mean temperature of the surroundings." This represents that uniform temperature at which a blacksurface would radiate with an intensity equal to the mean observed. If the globe thermometer temperature, the air temperature and the air velocity are known, the mean temperature of the surroundings can be ascertained from a special chart worked out for this purpose.

C H A P T E R III.

EXPERIMENTAL.

B.

REPEATABILITY TRIAL.

Introduction:

It is always highly desirable that a procedure intended for use as a test should give a high degree of repeatability. This question arose when it was decided to assess the differences in the physiological pattern prevailing during the experiment. The method most commonly practised for this purpose is repeating the test several times on the same animals. This method is subject to considerable error. Frequent repetition of same animals tends to set up accumulative effects in them, some of adaptive nature and some of reactive nature. Repetition of the test on several animals at longer intervals introduces error due to age, pregnancy, environmental factors and numerous other features. Reliance had to be placed, therefore, upon careful test design directed to eliminating the major external causes of variation, with the hope that statistical analysis of the results would reveal a desirable degree of repeatability.

(a) Materials and Methods.

(i) Animals and Animal Management.

In this study eight adult in-pig sows with live weights ranging from 340 lbs. to 425 lbs. were used. All animals were in early pregnancy and were to farrow within two weeks of each other. These pigs included two breeds - four Largewhites and four Berkshires.

All the pigs were kept in the Research Piggery at Massey College under conditions approximating good local herd conditions. These pigs were housed at nights and during the day had access to good quality pasture of perennial rye grass (*Lolium perenne*) and white clover (*Trifolium repens.*) Throughout the experimental period the animals were fed twice daily: at 7.00 a.m. with two pounds of meal (equal parts of barley and meat meal) and at 4.30 p.m. with approximately three gallons of whey.

In general, the pigs were in good health, they were docile and easy to handle.

(ii) Measurement and Techniques.

Data were obtained on four suitable test days in the summer between the 19th February and the 27th February, 1958. Suitable test days were those on which the skies were clear.

Rectal temperature,respiration and pulse rates, and skin temperatures were determined for each animal at approximately three hourly intervals at 6.30 a.m., 9.30 a.m. 12.30 p.m. and 3.30 p.m. on each test day. Three readings were made for each measurement at each test time.

Rectal temperature wasrecorded to the nearest tenth of one degree and were all taken by the same observer and the same th thermometer. A standard glass clinical thermometer was used, the accuracy of which was within - 0.1°F. Each reading was made with the thermometer inserted up to a stopper fixed four inches from the bulb. One-and-a-half minutes were allowed to elapse before reading.

A respiration count was made by observing flank movements for a period of half-a-minute. This was not always easy to do particularly when animals were grazing. Animals had to be dissuaded from moving or lying down while readings were made.

Pulse counts were determined by the palpation of the femoral artery of the right hind leg. These countswere made simultaneously with rectal temperature. Counts were made at half-a-minute intervals, for half-a-minute periods.

The procedure described by Patchell (1951) was followed for the measurement of skin temperature. A 'hack-saw' type thermocouple and a potentiometer obtained from the Dairy Research Institute were used. Details of the instrument are described by Patchell.

Measurements were made at three positions on each animal: left shoulder, rump and the right belly.

Two persons were required to carry out this measurement - one worked the potentiometer and the other held the thermocouple in position. The thermocouple was made to contact the skin surface with a slight pressure. After a few preliminary trials, the operator was able to obtain equilibrium quickly.

Dry and wet bulb temperaturesin the open were noted at each test time using a whirling psychrometer.

(iii) Treatment of Data.

The data was analysed by means of analysis of variance. Each analysis was of the special time-series as outlined by Wilm (1945). This allows the proper testing of some aspects of the analysis by appropriate error or interaction mean squares, but not of others.

Components of variance were worked out to show what proportion of the variance was associated with any source of variation.

To obtain repeatability estimates (r), i.e. how repeatable would the readings be if they were taken again on the same animals on similar days at similar times, the following formula was used:

$$r = \frac{\text{Component } s^2adt}{\text{Component } s^2adt + \text{Component } s^2r}$$

where

s^2a = variance due to animals within the breed.

s^2t = contribution to total variation due to diurnal changes.

s^2d = variance due to differences between daily measurements common to all animals and times.

s^2at = variance due to differences between the diurnal pattern of the animals.

s^2ad = variance due to differences between the animals in their overall daily responses.

s^2dt = variance to to differences in the daily pattern averaged over the four animals.

s^2adt = remaining variability after removal of above sources of variation i.e. variability of a particular animal, time and day.

s^2r = variance of readings for a particular animal at a particular time on a particular day.

(b) Results and Discussions.

All days were combined and separate analyses of variance were carried out for the two breeds for each one of the four variables i.e., rectal temperature,respiration rate, pulse rate and skin temperature.

Table 3 shows the analyses of variance with degrees of freedom, mean squares, percentage of the total components of variance associated with any source of variation, significance and repeatability of estimates.

Tables of mean values, together with the results of statisticaltests appear in the body of the thesis and the original data and detailed analyses of variance are presented in the appendix.

TABLE 3

TOTAL ANALYSES OF VARIANCE OF (a) RECTAL TEMPERATURE, (b) RESPIRATION RATE, (c) PULSE RATE (d) SKIN TEMPERATURE (RUMP, BELLY AND SHOULDER) AND REPEATABILITY ESTIMATES.

LARGEWHITES

Repeatability Estimates

Source of Variation	Degrees of Freedom				MEAN SQUARE, SIGNIFICANCE AND % OF TOTAL COMPONENTS OF VARIANCE																	
					Rectal Temperature (a)			Respiration Rate (b)			Pulse Rate (c)			(d) SKIN TEMPERATURE Rump			Belly			Shoulder		
	a	b	c	d	M.S.	S.	F.	M.S.	S.	F.	M.S.	S.	F.	M.S.	S.	F.	M.S.	S.	F.	M.S.	S.	F.
A	3	3	3	3	4.07		N.S.	806.32		N.S.	316.78		N.S.	17.50		N.S.	[illegible]		N.S.	7.00		N.S.
T	3	3	3	3	24.73	19.71	*	16078.23	30.31	*	1178.33	13.75	N.S.	638.43	61.00	**	239.10	32.37	**	604.43	64.12	**
D	3	3	3	2	1.57		N.S.	2059.33		N.S.	884.33	1.59	N.S.	79.45	0.30	N.S	49.45	2.00	N.S.	25.95		N.S.
A x T	9	9	9	9	4.82		*	702.30		N.S.	357.33	8.45	N.S.	7.67		N.S	42.32	20.56	*	11.45	4.00	*
A x D	9	9	9	6	0.62		N.S.	2279.30	10.11	N.S.	351.56	8.19	N.S.	2 .29	2.00	N.S	10.52		N.S.	2.88		N.S.
D x T	9	9	9	6	2.14		N.S.	3118.27	17.97	*	614.63	22.42	*	83.72	15.80	**	33.64	12.28	N.S.	72.13	25.19	**
A x T x D	27	27	27	18	1.58	75.96	**	1106.99	41.32	**	200.11	42.17	**	15.72	17.60	**	14.45	31.78	**	4.04	5.80	**
Readings	128	128	128	96	0.093	4.36		2.59			5.25	3.41		0.99	3.80		0.18	1.0		0.10	0.50	
	191	191	191	143																		
REPEATABILITY					0.84			0.99			0.93			0.83			0.96			0.93		

BERKSHIRES

Source of Variation	a	b	c	d	M.S.	S.	F.	M.S.	S.	F.	M.S.	S.	F.	M.S.	S.	F.	M.S.	S.	F.	M.S.	S.	F.
A	3	3	3	3	3.53	5.35	N.S.	744.67	0.50	N.S.	1571.57	6.65	N.S.	6.53		N.S.	27.90	0.80	N.S.	8.66		N.S.
T	3	3	3	3	72.70		**	12336.33	12.43	*	1043.23		N.S.	1076.33		**	495.00	2.01	**	[illegible]	29.09	**
D	3	3	3	2	16.30	1.33	**	5747.06	34.94	N.S.	100.97	2.51	N.S.	9.63	72.78	N.S	106.60	52.10	N.S.	43.65	56.97	N.S.
A x T	9	9	9	9	1.16	3.97	N.S.	601.33		N.S.	488.96		N.S.	6.73	0.30	N.S	14.34	2.70	N.S.	13.29	1.05	N.S.
A x D	9	9	9	6	0.61	5.51	N.S.	232.05	2.02	N.S.	425.46		N.S.	9.93		N.S	14.38	3.52	N.S.	21.19		N.S.
D x T	9	9	9	6	1.31	7.21	N.S.	2188.48	24.19	**	588.76		N.S.	92.59	18.85	**	78.58	27.17	**	85.59	0.62	**
A x T x D	27	27	27	18	1.57	63.31	**	456.56	25.32	**	695.83	75.01	**	7.58	6.05	**	7.35	10.98	**	14.74	8.20	**
Readings	128	128	128	96	0.012	13.30		3.63	0.61		45.55	15.77		0.76	2.00		0.15	0.69		2.09	4.06	
	191	191	191	143																		
REPEATABILITY					0.83			0.98			0.83			0.75			0.94			0.67		

N.S. = not significant
** = significant at 1% level
* = significant at 5% level

ANALYSIS OF VARIANCE.

Rectal Temperature:

Table 3 shows that there were no significant differences between animals, animals x days and days x times interactions in rectal temperature of the two breeds. Significant differences in both breeds were found between times throughout the day. This was expected as rectal temperature was shown to be highly correlated with air temperature (Robinson and Lee, 1941). The intervals between measurement times were three hours and there were definite changes in air temperature of these times. Day differences were not significant in the Largewhites but were highly so in the Berkshires. Days did not vary much but intensity of solar radiation appeared to have caused fluctuation in rectal temperatures of the Berkshires, i.e. it showed the effect of climate. The second order interaction animals x days x times were highly significant. When an animal was under stress individual characteristics became very marked. If they were not, the animal conformed to the habits of the herd. There were days when air temperatures were relatively high or the solar radiation was intense - sufficient to have caused stress. Stress along with hunger and thirst probably caused animal's rectal temperature response to change at different times on different days.

Respiration Rate:

Air temperature conditions were sufficient to show marked differences between times and interactions, days x times and animals x days x times in respiration rates in the two breeds. According to Robinson and Lee (1941) and Heitman and Hughes (1949) respiration rate increased when air temperature was in the range of 60°F. - 105°F. The range under the conditions of this experiment were 57°F. - 79°F., sufficient to have caused differences. That respiration rate was markedly influenced by climatic factors was evident.

Pulse Rate:

Only animals x days x times interaction was highly significant in both the breeds. Findlay (1950) gave the range in pulse rates for the pig between 60-90. Robinson and Lee (1941) showed that air temperature over 80°F. caused increased pulse rate. Wirth (1956) stated that exertion greatly increased the rates of pulse and that ten minutes of forced exercise produced an increase of over 60% in its rate. In view of the combination of the above three factors it was difficult to show direct climatic effects in this variable. That pulse rates were strong individual characteristics of animals was suggested . The differences between animals, times and days and their first order interactions were not significant suggested that the range in air temperature conditions prevailing during the trial was not severe enough to have brought about these differences.

Skin Temperature:

Skin temperature analyses of variance for the three positions (rump, belly and shoulder) show that there were no significant differences between animals. Thompson et al. (1951) showed that skin temperature did not change as rapidly as air temperature but it did change when air temperature was above 80°F. or when the intensity of solar radiation was high. Effect of air movement and lower temperature also brought about changes. Air temperature prevailing under the conditions of the experiment were not sufficiently severe to have brought about this effect. Time differences were highly significant for all positions in the two breeds. This was expected in view of the range in air temperature - a mean difference of 22°F. Days and animals x days differences were not apparent in any of the breeds for any position. This is again attributed to the condition of the atmosphere. Animals x times interaction was not significant for the Berkshire but were significant for the Largewhites for belly and shoulder positions. The variance due to this component was only 4% for the shoulder but 21% for the belly for the Largewhites. This is not quite clear but was probably associated with the posture of the animals prior to time of measurement, i.e. if the animal had been lying, the belly or shoulder would be in contact with grass and consequently such differences would be expected. Days x times interaction were highly significant for positions in both breeds (except belly in the Largewhites). This was expected in view of differences in weather conditions at a given time on different days.

The second order interaction animals x days x times were highly significant for all positions in both the breeds. Skin temperature was increased when animals exerted themselves (Wirth, 1956). That animals x days x times interaction differences were the result of such physiological phenomena was suggested.

Repeatability Estimates.

Repeatability estimates worked out for the four variables are presented in Table 4 together with similar estimates for cattle (Patchell, 1951; McDowell *et al.*, 1953; Seath and Miller, 1947), and buffaloes (Alim and Ahmed, 1958).

TABLE 4.

	1		2		3		4		5
	Present Trial		Patchell (1951)		McDowell *et al.* (1953)		Seath and Miller (1947)		Alim and Ahmed (1958)
	(i)	(ii)	(i)	(ii)			(i)	(ii)	(i)
Rectal Temperature	0.84	0.83		0.309	0.93	0.60	0.64	(1944) 15.2 (1945) 38.5	0.195
Respiration Rate	0.99	0.98	0.550	0.324	0.47	0.65	0.37	(1944) 0.420 (1945) 0.478	0.172
Pulse Rate	0.93	0.83	0.580	0.559					
Skin Temperature	0.83 0.96 0.93	0.75 0.94 0.67	0.425	0.107 0.713 0.849 } *					

	Animals.	Air Temp. Range of.	Comment.
1.	(i) 3 Largewhites (ii)3 Berkshires	57 - 79	Av. of 3 readings/time, 4 times daily for 4 days.
2.	Jerseys 24 month olds (dry)	62 - 70	(i) 4 readings/day treated separately for each cow. (ii) readings on similar types of days. * positions were shaved - left and right hips. 6 readings/position on 12 cows for 1 day.
3.	Jerseys 8-22month olds	105°F. for 6 hours in Test house	(i) Between April-July) (ii) Between Oct.- Jan.) measurement repeated at 2 month intervals.
4.	Jerseys Holsteins (in milk)	1944-65-93 1945-75-91	(i) Figures for 2 years combined - (14 consecutive days.) (15 consecutive days.) (ii) Measurement on 8 warm days.
5.	Buffaloes (dry, pregnant and in milk)	57.4-100.2	Based on 4 daily readings on 24 separate days.

It will be seen that these repeatabilities are not readily comparable in view of the differences in species, breeds, times, ages, weather conditions and treatment of data. Rectal temperature and respiration rates for the Largewhites and Berkshires are high and almost identical. With regard to pulse rates the differences between the breeds is only 10%; nevertheless it is high when comparisons are made with estimates from other workers' data. Although skin temperature repeatabilities are high for all three positions, rump and shoulder positions in the Berkshires show lower estimates as compared to values for Largewhites. Shoulder and belly positionswere expected to give lower estimates in view of the habits of the animals. When the animal lay on the grass the shoulder or belly position (depending on which side the animal lay since right side on the belly and left side on the shoulder were positions of measurements) was in contact with grass; consequently results depended on the posture of the animal before measurements were taken. There were times when belly position had to be dried with a piece of cloth. In spite of this, belly gave the best and highest estimates. It is believed that such high estimates could have found favour for these positions (belly and shoulder) when we consider that belly positionswere smooth and hairless in both breeds and shoulder position in the Largewhite was hairless due to constant rubbing against fence posts; consequently heating by way of solar radiation and physiological processes would be relatively uniform over these areas; also proper contact with junction of thermocouple was obtained. That the above two factors contribute to a markeddegree to the high repeatability estimates can be supported when we consider lower estimates for Berkshires whose shoulders were thickly covered with hair and the skin was rough and horny.

Patchell (1951) also obtained higher estimates in cattle when the positions were shaved.

The rump position in all animals in both the breeds were comparable and was not subjected toshade or contact when they lay on the grass. Difference in the estimate for this position between the two breeds was only 8% as compared to 26% for the shoulder. The 'hack-saw' type thermocouple used for skin temperature measurements was easy to manipulate on the rump and facilitated quick reading.

In view of these advantages rump position was most acceptable for position effect for skin temperature measurement.

CHAPTER IV

DIURNAL VARIATION.

Introduction:

Many conditions are capable of causing variations in body temperature, respiration rate, pulse rate and skin temperature, among which may be mentioned age, sex, season, time of day, environmental temperature, exercise, eating digestion and drinking water. Variations related to the time of day are designated as diurnal variations. The extent and time of such changes vary somewhat in different species. In man for instance, the maximum body temperature occurs in the early afternoon and the minimum early in the morning. In cows, Kriss (1921) found that rectal temperature to be practically constant in the morning and in the afternoon until about 2.30 p.m. from which time until about 5.00 p.m., it gradually rose. Gaalas (1945) reported that the rectal temperature of the cow was regularly higher in the afternoon than in the morning irrespective of season or month. Similar reports have been made by Patchell (1951) in cows. The writer is not aware of any information of this nature with regard to the pig.

In this project an investigation into the diurnal trend of the following four physiological variables viz., rectal temperature, respiration rate, pulse rate and skin temperature of two breeds of pigs was made and the findings reported.

(a) MATERIALS AND METHODS.

(1). **Animals and Animal Management:** The experimental animals consisted of three Largewhite and three Berkshire sows, which had been used in the repeatability trial. Treatment details were similar to those of the earlier trial. All animals were in good health throughout the trial.

Measurement and Techniques: Thirteen observations were made during each of four twenty-four hour periods during the month of March, 1958. At each observation rectal temperature, respiration and pulse rates were recorded.

Observations were taken at 8.00 p.m., 10.00 p.m., 12.00 midnight, 2.00 a.m., 4.00 a.m., 6.00 a.m., 8.00 a.m., 10.00 a.m., 12.00 noon, 2.00 p.m., 3.30 p.m., 4.15 p.m. and 6.00 p.m.

Seven observations were made of skin temperature on each animal each day at 6.00 a.m., 8.00 a.m., 10.00 a.m., 12.00 noon, 2.00 p.m., 4.00 p.m. and 6.00 p.m., on four separate days during the months of February and early March, 1958.

Measurement techniques employed here were similar to those carried out for repeatability measurements.

Dry and wet bulb measurements were recorded at the beginning of each test time.

Treatment of Data: The data were analysed by means of analyses of variance. Each breed was treated separately for each of the four variables. Each analysis was of a special time-series type as outlined by Wilm (1945). This allows proper testing of some aspects of the analysis by appropriate error or interaction mean squares, but not of others. Subsequently, correlation and regression analyses were carried out.

To test breed differences at any particular time or times on any day or days the following method was used.

Comparison of breed means using within breed estimates of variance at a particular time -

e.g. at 12.00 noon, the (± S.E) breed rectal temperatures (average on four days) for the three animals were -

LARGEWHITES	102.74 ± 0.28
BERKSHIRES	103.31 ± 0.16

to test

$$\frac{103.31 - 102.74}{\sqrt{(0.16)^2 + (0.28)^2}}$$

and an approximate t test is given by Goulden (1952).

RESULTS.

Table 5 shows analysis of variance with degrees of freedom, mean squares and significance for the two breeds separately. Complete analyses of variance for each variable and breed are given in Appendices XX111 - XXX

In Figures II, III, IV and V are shown graphs of diurnal variations in rectal temperature, respiration rate, pulse rate and skin temperature for individual pigs. The points for each test time were the means of readings taken on four days.

TABLE 5 TOTAL ANALYSES OF VARIANCE OF (a) RECTAL TEMPERATURE, (b) RESPIRATION RATE, (c) PULSE RATE AND (d) SKIN TEMPERATURE FOR LARGEWHITES AND BERKSHIRES.

Source of Variation	Degrees of Freedom				Mean Square and Significance							
					(a)		(b)		(c)		(d)	
	a	b	c	d	M.S.	F	M.S.	F	M.S.	F	M.S.	F
LARGEWHITES												
Animals	2	2	2	2	3.40	7.39**	2014.00	4.46*	39.50	0.31 N.S.	0.65	1.16 N.S.
Times	12	12	12	6	29.39	15.15**	32241.42	15.74**	4306.54	8.92**	200.47	37.97**
Days	3	3	3	3	6.20	3.19*	2673.03	1.30 N.S.	132.13	2.74 N.S.	23.40	4.43**
Animals x Times	24	24	24	12	0.46	0.63 N.S.	451.58	1.58 N.S.	24.09	0.43 N.S.	0.56	1.51 N.S.
Animals x Days	6	6	6	6	0.3[illegible]	0.49 N.S.	133.70	0.47 N.S.	125.43	2.23*	0.17	0.46 N.S.
Days x Times	36	36	36	18	1.94	2.66**	2048.96	7.19**	481.26	8.57	5.28	14.27**
Animals x Days xTimes	72	72	72	36	0.73		285.00		56.15		0.37	
TOTALS	155	155	155	83								
BERKSHIRES												
Animals	2	2	2	2	0	0 N.S.	6.00	N.S.	881.80	6.66**	0.25	0.34 N.S.
Times	12	12	12	6	31.44	20.68**	26188.67	29.29**	3316.66	12.48**	168.33	26.63**
Days	3	3	3	3	5.93	1.67 N.S.	4350.73	3.78*	785.03	2.95 N.S.	27.70	3.75**
Animals x Times	24	24	24	12	0.13	0.19 N.S.	85.71	0.66 N.S.	31,85	2.14*	0.33	0.75N.S.
Animals x Days	6	6	6	6	3.55	5.14**	176.47	1.35 N.S.	132.47	8.92**	0.73	1.66 N.S.
Days x Times	36	36	36	18	1.52	2.20**	1124.02	8.63**	265.70	17.88**	6.32	14.36**
Animals x TimesxDays	72	72	72	36	0.69		130.23		14.86		0.44	
TOTALS	155	155	15	83								

** = Significant at 1% level.
* = Significant at 5% level.
N.S.= Non-significant.

Table 5 and 6 show the range, standard deviation (derived from the error variances of the appropriate analyses) and coefficient of variation for each breed of the four measurements.

TABLE 6.

RANGE, MEAN, STANDARD DEVIATION AND COEFFICIENT OF VARIATION FOR AIR TEMPERATURE, RECTAL TEMPERATURE, RESPIRATION RATE AND PULSE RATE.

		LARGEWHITES			BERKSHIRES		
	Air Temp. °F.	Rectal Temp. °F.	Resp. Rate/ Min.	Pulse Rate Beats/ Min.	Rectal Temp. °F.	Resp. Rate/ Min.	Pulse Rate Beats/ Min.
Range	50.5 - 81.5	99.7 - 104.9	9-281	52-168	97.2 - 104.4	8-197	56-151
Mean	66.5	101.1	56.5	90.6	101.3	53.0	88.2
Standard Deviation	5.5	0.34	7.96	2.20	0.55	3.65	4.83
Coefficient of Variation %	8.4	0.33	15.41	2.50	0.54	6.32	5.80

TABLE 7. RANGE, MEAN, STANDARD DEVIATION AND COEFFICIENT OF VARIATION FOR AIR TEMPERATURE AND SKIN TEMPERATURE.

		LARGEWHITES	BERKSHIRES
	Air Temp. °F.	Skin Temp. °F.	Skin Temp. °F.
Range	57 - 81.5	84.6 - 94.3	84.1 - 95.0
Mean	70	90.40	91.00
Standard Deviation	6.16	0.39	1.39
Coefficient of Variation %	8.85	0.44	1.52

Components of Variance:

From the analysis of variance, components of variance were derived to show what proportion of the total variance was associated with any given source of variation. These are shown in

Table 8.

TABLE 8 * COMPONENTS OF VARIANCE DERIVED FROM ANALYSES OF VARIANCE FOR RECTAL TEMPERATURE, RESPIRATION RATE, PULSE RATE AND SKIN TEMPERATURE.

	LARGEWHITES								BERKSHIRES							
Source of Variation	Rectal Temperature		Respiration Rate		Pulse Rate		Skin Temperature		Rectal Temp.		Respiration Rate		Pulse Rate		Skin Temperature	
	Actual	%	Actual	%	Actual	%	Actual	%	Actual	%	Actual	%	Actual	%	Actual	%
A	0.05	64.00	23.40	0.67			0.02	0.12					16,67	3.32		
T	2.35	1.40	2473.40	70.39	318.79	58.86	16.25	86.44	2.49	55.70	2093.72	79.30	254.24	50.59	13.50	82.52
D	0.13	3.00	16.00	0.46	19.75	3.65	0.47	2.50	0.96	21.48	81.55	3.09	133.20	26.50	0.44	2.69
A x T			128.00	3.64			0.05	0.27								
A x D					5.25	0.97			0.05	1.10	3.56	0.01			1.02	0.12
D x T	0.40	11.00	588.00	16,73	141.70	26.17	1.64	8.72	0.28	6.26	331.26	12.55	83.61	16.64	1.96	11.98
A x T x D	0.73	20.00	285.00	8.11	56.50	10.36	0.37	1.95	0.69	15.44	130.23	4.94	14.86	2.96	0.44	2.69
TOTALS	3.66		3513.80		541.64		18.80		4.47		2640.32		502.58		16.36	

* Only positive values are given.

Simple correlation coefficients between the observed average air temperature and the values for the four variables were calculated. In Table estimates for each pig for the four days continued and estimates for each breed for the four days combined are given.

TABLE 9 BREED CORRELATION COEFFICIENTS FOR RECTAL TEMPERATURE; RESPIRATION RATE, PULSE RATE AND SKIN TEMPRRATURE.

	LARGEWHITES				BERKSHIRES			
	Pig 1	Pig 3	Pig 7	BREED	Pig 2	Pig 4	Pig 8	BREED
Rectal Temperature (d.f. 50)	0.66	0.73	0.59	0.66	0.76	0.76	0.65	0.72
Respiration Rate (d.f. 50)	0.86	0.65	0.60	0.70	0.67	0.65	0.70	0.67
Pulse Rate (d.f. 50)	0.47	0.66	0.64	0.59	0.56	0.68	0.66	0.63
Skin Temperature (d.f. 26)	0.87	0.81	0.83	0.84	0.84	0.70	0.79	0.78

All estimates were highly significant.
From Snedecor's table for tests of significance

50 d.f. r = 0.354 at the 1% level
and 26 d.f. r = 0.478 at the 1% level.

Correlation coefficients between Air temperature and

Correlation coefficients between Air temperature and each one of the four variables for individual pigs on each day for the two breeds are given in Appendices

Regression analyses were worked out and given in Table Two sets of figures are provided. Firstly, regression coefficients of each pig for the four days combined and secondly regression coefficients for each breed for the four days pooled together. Standard errors are also shown along with each coefficient.

TABLE 10.

REGRESSION COEFFICIENTS and STANDARD ERRORS.

	LARGEWHITES				BERKSHIRES			
	1	3	7	Breed	2	4	8	Breed
Rectal Temperature	0.157 ±0.022	0.171 ±0.022	0.139 ±0.026	0.155 ±0.010	0.205 ±0.024	0.161 ±0.019	0.110 ±0.005	0.160 ±0.012
Respiration Rate	4.876 ±0.39	4.612 ±0.70	4.734 ±0.88	4.836 ±0.41	4.123 ±0.65	4.015 ±0.66	4.025 ±0.58	4.055 ±0.83
Pulse Rate	1.289 ±0.33	1.868 ±0.30	1.526 ±0.26	1.580 ±0.21	1.417 ±0.27	1.445 ±0.17	1.495 ±0.24	1.450 ±0.20
Skin Temperature	0.56 ±0.010	0.54 ±0.076	0.59 ±0.004	0.56 ±0.011	0.59 ±0.074	0.49 ±0.099	0.65 ±0.095	0.57 ±0.050

The overall regression coefficients were not significantly different for any of the four variables between the two breeds i.e. these data provided no indication that the regression lines for different pigs belonged to a different population.

Breed Differences show the means with standard errors of the four variables of each breed at any particular time. These estimates are provided in Table 11 . The differences between corresponding breed means were all non-significant i.e. both breeds showed consistently similar reactions to the prevailing conditions throughout the experiment.

TABLE 11

COMPARISON OF BREEDS FOR RECTAL TEMPERATURE, RESPIRATION RATE, PULSE RATE, SKIN TEMPERATURE AND STANDARD ERRORS.

	LARGE WHITE				BERKSHIRE			
Time	Rectal Temperature	Respiration Rate	Pulse Rate	Skin Temperature	Rectal Temperature	Respiration Rate	Pulse Rate	Skin Temperature
8.00 p.m.	101.74 ± 0.35	19.67 ± 1.21	81.00 ± 1.47		101.04 ± 0.27	23.67 ± 1.30	82.00 ± 3.43	
10.00 p.m.	100.49 ± 0.20	14.17 ± 0.31	75.00 ± 1.80		100.13 ± 0.40	15.33 ± 0.31	78.00 ± 2.29	
12.00 mid-night	99.50 ± 0.13	13.08 ± 0.31	72.00 ± 0.86		99.74 ± 0.31	13.83 ± 0.31	73.00 ± 2.77	
2.00 a.m.	98.70 ± 0.14	12.07 ± 0.31	69.00 ± 0.44		99.11 ± 0.50	12.50 ± 0.31	71.00 ± 3.09	
4.00 a.m.	98.72 ± 0.49	10.83 ± 0.57	67.00 ± 0.76		98.52 ± 0.68	10.67 ± 0.57	69.00 ± 3.31	
6.00 a.m.	99.90 ± 0.09	24.83 ± 1.52	74.00 ± 0.93	84.85 ± 0.16	99.34 ± 0.31	23.70 ± 1.00	72.00 ± 3.35	84.41 ± 0.17
8.00 a.m.	100.38 ± 0.16	33.50 ± 2.60	88.00 ± 1.88	86.15 ± 0.30	100.27 ± 0.27	34.00 ± 1.70	82.00 ± 2.02	86.28 ± 0.11
10.00 a.m.	101.42 ± 0.17	76.50 ± 3.00	105.00 ± 1.04	89.27 ± 0.21	101.29 ± 0.25	70.00 ± 2.60	99.00 ± 1.24	90.91 ± 0.04
12.00 noon	102.74 ± 0.28	155.58 ± 17.20	118.00 ± 1.31	91.99 ± 0.09	103.31 ± 0.18	141.00 ± 2.33	116.00 ± 2.34	93.02 ± 0.04
2.00 p.m.	102.41 ± 0.18	123.67 ± 2.60	113.00 ± 2.55	93.63 ± 0.57	102.41 ± 0.18	118.00 ± 3.50	109.00 ± 3.19	94.22 ± 0.06
4.00 p.m.				94.19 ± 0.06				94.79 ± 0.16
4.15 p.m.	102.72 ± 0.03	76.08 ± 13.70	102.00 ± 0.23		102.67 ± 0.12	61.33 ± 3.20	92.00 ± 1.55	
6.00 p.m.	102.19 ± 0.09	36.42 ± 6.70	97.00 ± 2.60	92.89 ± 0.06	102.04 ± 0.10	44.67 ± 5.20	93.00 ± 4.23	93.38 ± 0.20

ALL DIFFERENCES BETWEEN BREEDS ARE NON-SIGNIFICANT. P 0.05 (approximate t-test - after Goulden, 1952).

D I S C U S S I O N

RECTAL TEMPERATURE.

Analysis of Variance:

Table 5 showed that there was a highly significant animal difference within the Largewhite breed but not in the Berkwhires. The difference within the Largewhite breed could be attributed to the behavious of the animals during the trial, i.e. animals were definitely individuals in their habits. In the case of Berkshires the animals behaved as a group. The difference could also be inherent.

The analysis also showed highly significant diurnal variations in both breeds. This was expected since the air temperature and conditions prevailing during this trial which was during mid-summer were severe enough to cause differences between times of the day in the rectal temperature of the animals. This condition was shown by Robinson and Lee (1941) and Heitman and Hughes (1949) in their psychrometric chamber studies. Day differences were again significant in the Largewhites but not in the Berkshires. Day to day differences in air temperature was sufficient to have caused this rectal temperature difference in view of the condition of the Largewhites. The Largewhites in general were poorer in condition although by no means unhealthy. Moreover, on the first and second days, fly population was greater. Largewhites with sunburn skin were constantly pestered so that they exerted themselves much more. This exertion could have contributed to day differences. The interaction Animal x times were non-significant in both breeds i.e. all animals in both breeds showed consistently similar diurnal variation. Animal x day interaction were highly significant in the Berkshires only showing that their rectal temperatures were not consistent on all four days. On bright hot days the Berkshires spent most of the time sitting or lying with no inclination to forage. Day x time interaction was again highly significant for both the breeds indicating that rectal temperature was different on different days and different times. This difference waxse expected because of the different weather conditions at a given time on different days.

Components of Variance:

Table 8 of Components of Variance expressed as percentage shows that animal affects accounted for 64% of the total variance in rectal temperature of the Largewhites and the remainder of the 36% were due to animal x day x time interaction (20%) and day x time (11%). Day variance accounted for only 3% and time 1.4%. In contrast to the above, the Berkshires accounted for 56% due to time, 21.5% for days, 15.4% for animal x day x time and 6.3% for day x time. Variance due to animal affects were nil. This would mean that in the Largewhite, climate was not the main cause for differences in the rectal temperature.

Correlation and Regression Analysis:

Table 9 shows simple correlation coefficients between air temperature and rectal temperature for each pig and for all pigs of each breed. Correlation coefficients of similar combination have been produced by Patchell (1951) for cattle and by Alim and Ahmed (1958) for buffaloes.

The statistics r gives the degree of relationship between two variables. When the r is squared then it represents the proportion of the total variance which can be explained by the relationship. Thus, even though a high correlation was obtained between air temperature and rectal temperature, the proportion of the total variance explained by the relationship is relatively small. When correlation coefficients are squared, air temperature-rectal temperature r* can explain at the most, approximately 44% and 52% of the variance for the Large whites and the Berkshires respectively. Nevertheless these correlations compare very favourably with other workers' results for cattle and buffaloes.

Whether air temperature alone can bring about such a difference in the rectal temperature is doubtful, especially the air temperature encountered under the conditions of the experiment. Robinson and Lee (1941) and Heitman and Hughes (1949) in their psychrometric chamber studies have shown that animals could tolerate air temperature of 80°F. - 90°F. for 7 hours before a rectal temperature of 105°F. was obtained. In the present experiment under field conditions, a high response in rectal temperature was obtained, at an air temperature of only 69°F. when the solar radiation was intense. The effect of solar radiation is adequately reported by Fletcher (1949).

In view of the high correlation between air temperature and rectal temperature reported herein and by other workers, it is thought that intensity of solar radiation is of considerable importance and that this study is in support of Fletcher's work.

The linear regression coefficients are of interest. Table 9 shows the estimates.

* correlation coefficient.

A 1°F. rise in air temperature on the average produced 0.155°F. and 0.166°F. in rectal temperature. That the two breeds show a very similar behaviour in rectal temperature means that all pigs belonged to a common population with regard to the effect of air temperature on rectal temperature rise under the range of air temperature in this study.

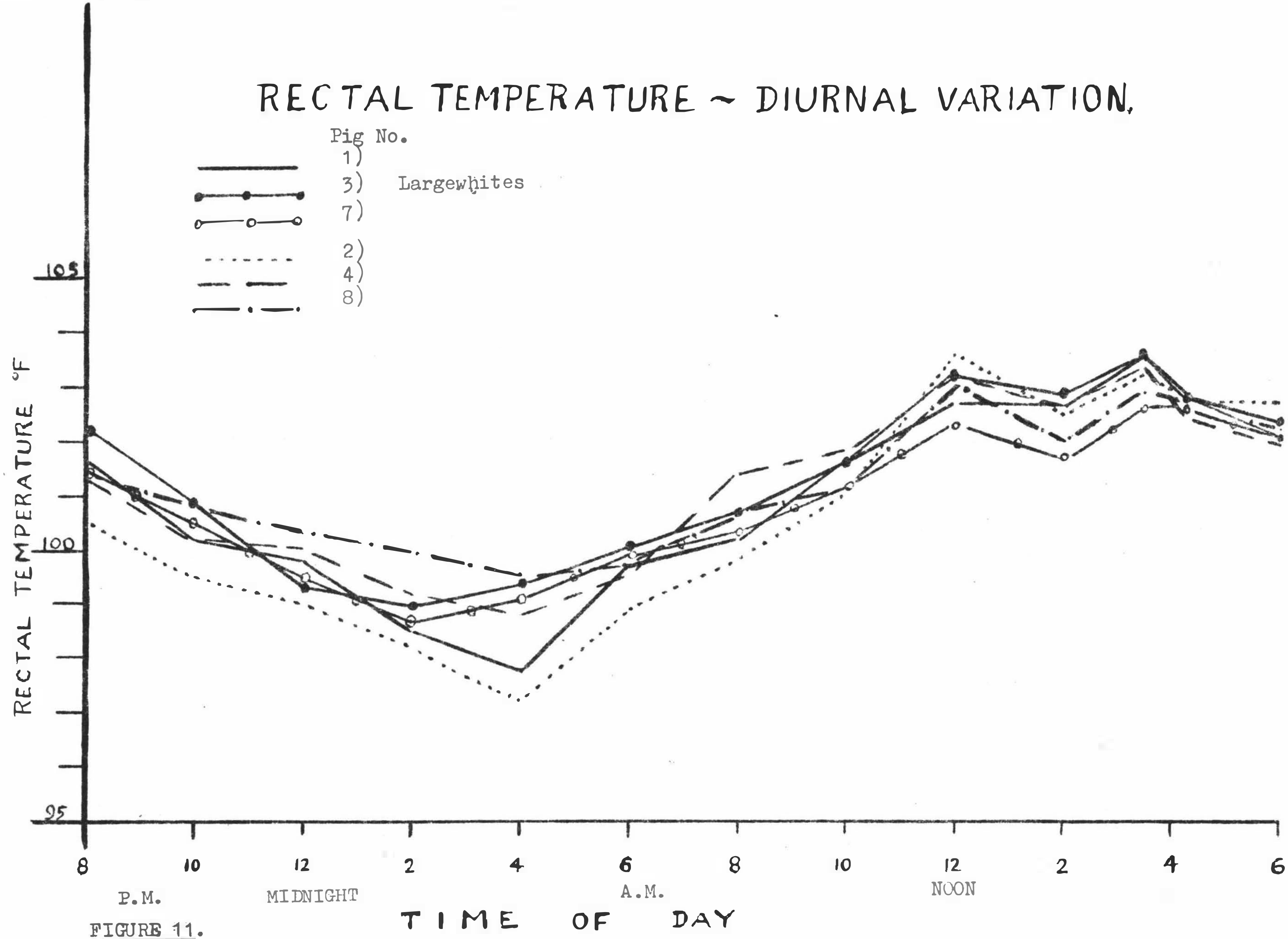

RECTAL TEMPERATURE ~ DIURNAL VARIATION.
Pig No.
1)
3) Largewhites
7)
2)
4)
8)
105
100
95
RECTAL TEMPERATURE °F
8
10
12
2
4
6
8
10
12
2
4
6
P.M.
MIDNIGHT
A.M.
NOON
TIME OF DAY

FIGURE 11.

GRAPHS:

Figure II illustrates the diurnal variation in rectal temperature. It can be seen that all pigs show a similar general trend and the differences within the breed and between breeds are very slight.

Rectal temperature variation show a very similar pattern to that reported for cattle by Varrier Jones and Sims Woodhead (1915) and Mabon and Hutchinson (1954). Temperature tended to be lowest at 2.00 - 4.00 in the morning (98.7°F. and 98.5°F. for Largewhites and the Berkshires respectively) rising markedly from then on to 6.00 in the afternoon. It is suggested that these low values are due partly to the effect of bulk of whey fed and partly to environmental temperature, the latter factor directly affecting the animal heat loss. The rise in rectal temperature at 6.00 in the morning coincides with rise in air temperature and this effect is double-fold since animals were fed at 5.45 a.m. Also before feeding, the animals are very restless and exert themselves considerably.

After the 12.00 noon measurements all pigs were given shelter. The hours that followed showed a drop in the rectal temperature in both the breeds, sufficient to make the animals comfortable. On an average approximately 0.3°F. and 0.9°F. decreases were noticed for the Largewhites and the Berkshires respectively. A similar decrease in the rectal temperature was shown by Robinson and Lee (1941). They showed that three Berkshire males, weighing approximately 130 pounds liveweight and kept in a psychrometric chamber and subjected to various temperatures and humidities were under extreme distress when air temperature was held at 85°F. for about five hours. At 106°F. in air temperature, the rectal temperatures were 105.6°F. and this condition the pigs were not able to tolerate for more than two hours. When the animals were removed from the chamber, the rectal temperatures recovered to normal in less than an hour.

They further showed that pigs with abnormally high rectal temperatures when soused or given cool drinking water showed marked improvement. A very similar effect was produced in the present experiment when the animals were fed whey (temperature of whey was 61°F.) at 4.00 in the afternoon. A steady fall in the rectal temperature from then on can be seen in the graph. This lowered rectal temperature is only a temporary effect. That other factors contribute to the decline in this variable is suggested in view of the fall in air temperature and lowered activity of the animal i.e. disinclination to forage after a bulky feed of whey.

It is difficult to state exactly at what rectal temperature distress signs appear. Some animals tend to have a relatively high rectal temperature even at rest, especially after concentrate feeding while others show very high respiration rates (in this study pig No. 7 showed a rectal temperature of 101.4°F. and yet respiration rate was 281 beats per minute) with low rectal temperatures. It is therefore not quite clear how accurately rectal temperature can be used as an indication to stress in pigs in view of the large range for normal rectal temperature - 98.3°F. to 104°F. given by Findlay (1950).

Respiration Rate.

Analysis of Variance:

Air temperature conditions were sufficient to show a marked difference in respiration rate between animals in the Largewhites. According to Heitman and Hughes (1949) the critical environmental temperatures at which the increase in respiration rate became marked varied with breed. Although animals in both breeds showed high respiration rates, individuals in the Largewhites were very inconsistent. Pig No. 1 showed a remarkably low rate as compared to her mates Nos. 3 and [illegible]. There appeared to be a definite inherent difference within this breed. Times throughout the day were highly significant in both breeds, especially between the hours of 8.00 in the morning and 6.00 in the afternoon.

Day differences were significant in the Berkshires only. Similar differences were expected in the Largewhites but did not appear. This is not quite clear but it appears that respiration rates were consistently high for all the Largewhites each day in view of their activity. The interaction day x times were highly significant for both breeds. This suggests that respiration rate responses are the result ofclimate, that is, with change in temperature during the day there was change in respiration rates.

Components of Variance:

In both breeds respiration rate variances were mainly due to time of day, the Largewhites showing 70.39% and the Berkshires 79.30%. Variances due to day x time and animals x time x day interactions also appear but to a lesser extent. Animal x time interaction variance appear for Largewhites but not for Berkshires. However, this difference is only 3.64%. On the other hand 3.56% variance due to interaction animal x day appear in the Berkshires and no such variance is shown for the Largewhites. Variance due to animals are negligible for both breeds.

Correlation and Regression Analyses:

As indicated for rectal temperature, correlation coefficients between air temperature and respiration rate is high. This correlation can explain only 49% and 45% of the variance for the Largewhites and the Berkshires respectively - the major portion remains unexplained. These correlations are relatively high when comparison is made with similar work for cattle and buffaloes.

Robinson and Lee (1941) and Heitman and Hughes (1949) in their studies showed high correlation between air temperature and respiration rate only when the air temperature was 60°F. and over. At these temperatures respiration rates of over 200 beats per minute were obtained. In the present trial under field conditions 281 beats per minute were obtained with the air temperature at 69°F. The factors known to have brought about this condition was the intensity of solar radiation, the continuous movement and activity of the pig and the air temperature.

The linear regression coefficients for respiration rates show that in the Largewhites there was on an average, an increase of 4.386 respirations per minute for each °F. increase in air temperature as compared to a corresponding increase of 4.055 respirations per minute for the Berkshires. Although the rates for the Largewhites' increase were 19.2% higher than that obtained

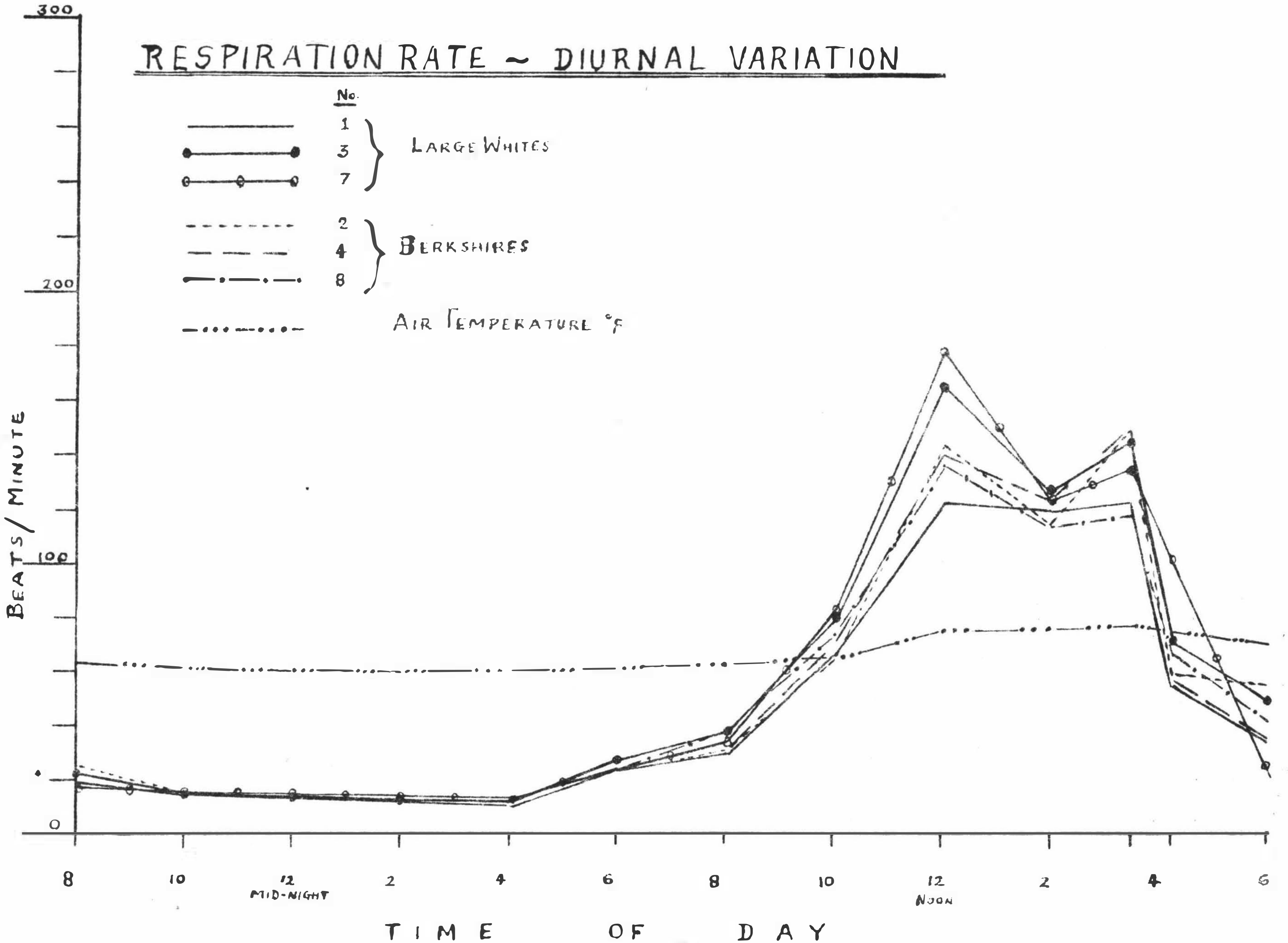

RESPIRATION RATE ~ DIURNAL VARIATION
No.
1
3
7
LARGE WHITES
2
4
8
BERKSHIRES
AIR TEMPERATURE °F
BEATS / MINUTE
300
200
100
0
8
10
12
MID-NIGHT
2
4
6
8
10
12
NOON
2
4
6
TIME OF DAY

FIGURE III.

for the Berkshires, the differences between the two breeds were not statistically significant.

GRAPHS:

Figure III shows that respiration rate follows a similar pattern to that already described for rectal temperature. Respiration rate begins to rise when the air temperature is in the range of 60°F.- 105°F. (Robinson and Lee, 1941), the rise being small at the lower temperatures, very great between 80°F. to 95°F. and a tendency to reach its maximum value around 105°F. The figure shows that the rise in the rate tended to be very marked from 8.00 in the morning onwards until 4.00 in the afternoon, after which there was again a very steep drop. The respiration rate between 6.00 in the afternoon and 6.00 in the morning tended to be almost constant. The pig at these times, was at complete rest and at the same time air temperature was sufficiently low. Lowered activity and air temperature reduce respiration rates to the minimum. The lowest rates recorded were at 4.00 in the morning for both breeds, 8 and 9 respirations per minute for the Largewhites and the Berkshires respectively. As for rectal temperature, respiration rate for both the breeds showed a marked decrease at 12.00 noon when the animals were provided shade.

After each feed, respiration rate is difficult to count. At these times respiration rate seems to take the form of breathing,in which there occurs a complete cessation of respiration for five to ten seconds followed by a shallow then by normal breathing, which again becomes shallow, and is regularly succeeded by a new respiratory hiatus. According to Wirth (1956) active foraging, excitement, fever and high environmental temperature cause respiration rate to accelerate greatly. It is therefore difficult to suggest any one single factor that influences or affects this variable.

The maximum rate recorded in this experiment was 281 respirations per minute for pig No. 7 at 12.00 noon when the air temperature was only 69°F. The explanation for this can be attributed to solar radiation. The effect was sufficient to exceed the cooling ability of the pig since the pig is said to possess no functional sweat glands (Davidson, 1946) upon its general body surface and that insensible cutaneous evaporation is restricted in view of the fatness of the animal. Consequently, close-mouthed panting is replaced by open-mouthed breathing. As a result, high respiration rate is not uncommon in adult animals when a condition prevails to cause distress due to over heating. That sunlight plays a major role can be shown by the fact that provision of shade lowered respiration rate of pig No. 7 from 281 to 85 breaths per minute in just over 30 minutes with the air temperature showing a further increase from 69°F. to 73°F. - a difference of 196 breaths per minute in approximately 30 minutes even though the air temperature had risen 4°F.

Like the rectal temperature study, it is not quite clear at which temperature,increased respiration rate begins to rise, especially under the conditions of this experiment. Robinson and Lee (1941) gave a range of 60°F. - 105°F. for respiration rate rise under controlled conditions in a psychrometric chamber study. Similar controlled studies could be investigated under field conditions if the animals are held in a small yard and their movements restricted.

Pulse Rate.

Analysis of Variance:

Times, animal x day and day x times were all highly significant for the two breeds for pulse rates. These were to be expected since pulse rate appears to be a strong individual characteristic and depends markedly on the activity of the animal. The animal differences in the Largewhites were non-significant indicating that all animals were consistent in their pulse rates. This is not quite clear but it appears that pulse rate is inherently similar in the three animals. Animal differences were highly significant for the Berkshires. This was probably due to the fact that the normal pulse rates of pigs have a wide range - 60 to 90 beats per minute (Wirth, 1956). The range is considerably large and it is likely that animals were inherently different in this characteristic. Animal x time were only significant for the Berkshire i.e. animals were not consistently similar in the diurnal variation in pulse rate response. This is apparent in Figure III.

Components of Variance:

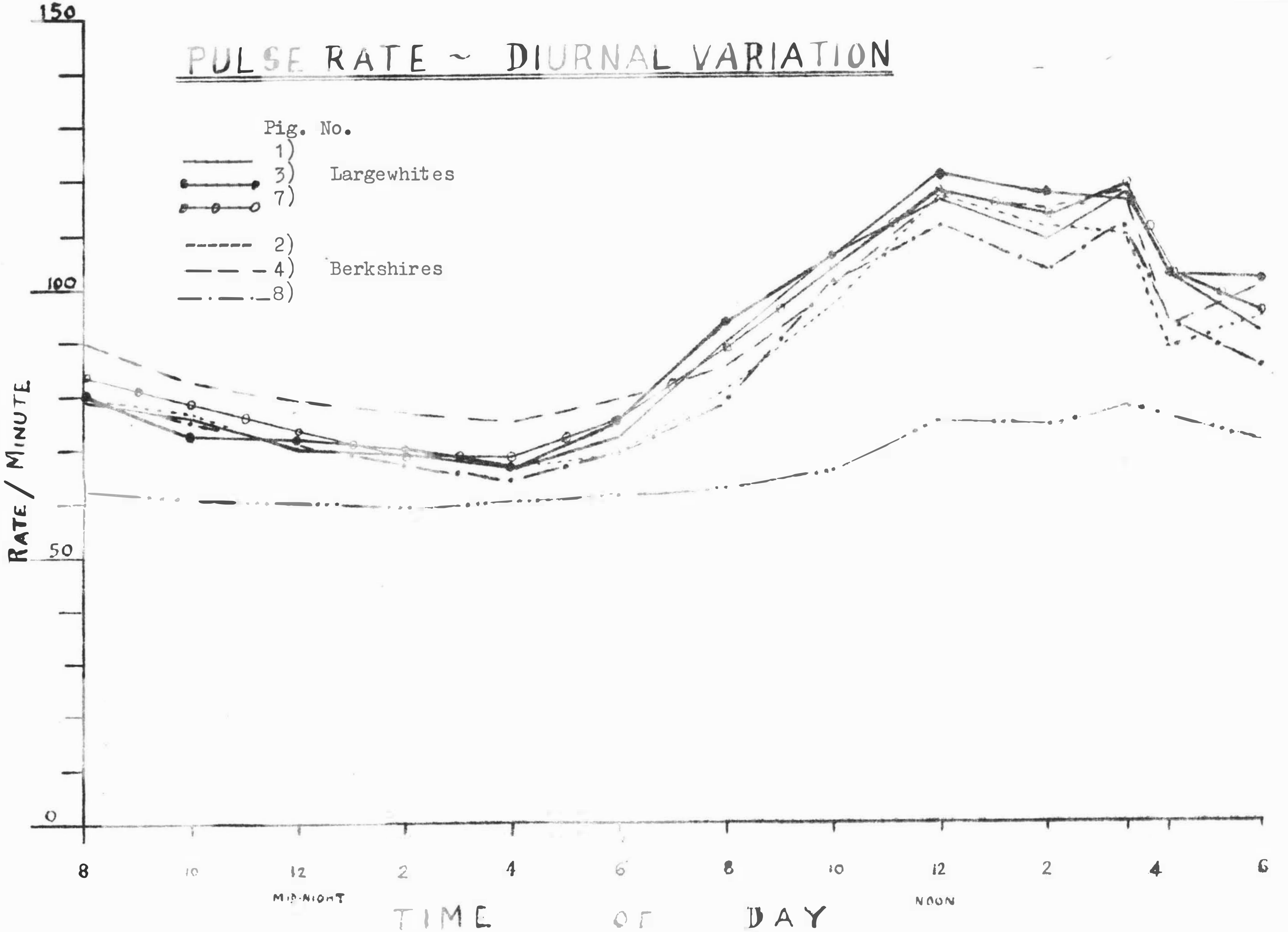
In both the breeds pulse rate variance was mainly due to time of day - 58.9% and 50.6% for the Largewhites and the Berkshires respectively. This major difference due to time of day suggested that environmental temperature does affect pulse rate. The Largewhites show 26.2% due to day x time variance while the Berkshires' variance was only 16.6% due to this interaction. Berkshires however, showed day variance of 26.5% while the Largewhites showed only 3.7%. Both breeds showed variances due to second-order interaction animal x time x day and these were small. Animal variances were small for the Berkshires but negligible for the Largewhites.

Correlation and Regression Analyses:

Pulse rate correlation coefficients were determined in a similar manner to Rectal temperature and Respiration rate. It will be seen from the Table that air temperature - pulse rate gave the lowest r values indicating that pulse rate was not as well correlated with air temperature as compared to the other three variables. Pig no. 1 showed lowest estimate. Although all estimates were highly significant it was debatable that in view of the air temperature range prevailing under the experimental condition, such a correlation was acceptable. When the r was squared it will be seen that only 35% and 40% of the variance can be explained for Largewhites and Berkshires respectively. These correlations are extremely high when comparison is made with other workers' results for cattle and buffaloes. Heitman and Hughes (1949) produced a negative correlation between air temperature and pulse rate.

However, from the present study it is apparent that pulse rate is associated with factors such as excitement as exercise, feeding, posture, pregnancy, activity, environmental temperature and numerous others. It is therefore difficult to relate this variable to environmental temperature effects. That environmental temperature affects response in pulse rate is supported but it is extremely difficult to even suggest at what range in air temperature it begins to rise.

Linear regression coefficients given in Table show that on an average, in the Largewhites, an increase of 1.580 beats per minute in pulse is associated with 1° rise in air



PULSE RATE ~ DIURNAL VARIATION
Pig. No.
1)
3) Largewhites
7)
2)
4) Berkshires
8)
150
100
50
0
RATE / MINUTE
8
10
12
MID-NIGHT
2
4
6
8
10
12
NOON
2
4
6
TIME OF DAY

FIGURE IV.

temperature as compared to a corresponding increase of 1.450 beats per minute for the Berkshires. Largewhites and Berkshires show considerable variability within the breed than between the breeds. For instance, in the Largewhites, pig nos. 3 and 7 show an increase of 45% and 17% respectively over pig no. 1 for every 1°F. rise in air temperature. Such a difference is also seen in the Berkshires. However, the overall differences between the two breeds are not large and certainly not statistically significant. In the Largewhites the rate of increase is approximately 9% higher than that for the Berkshires.

GRAPHS:

Figure IV illustrates the diurnal variations in the pulse of the pig; it shows a similar pattern to respiration rate but the rise tends to be moderate. Evidence with regard to the effect of temperature on pulse rate of the pig is conflicting. Robinson and Lee (1941) have claimed rises in pulse rate with increase in air temperature while Heitman and Hughes (1948) claim decreases with increase in air temperature. Both teams of workers worked in psychrometric chambers. The maximum pulse beat per minute was obtained at 3.30 in the afternoon when the air temperature was 81.5°F.

Pulse, like respiration rate is subject to changes due to a number of factors i.e. species, size, age, condition, sex, pregnancy, partuirition, lactation, excitement, exercise, position, ingestion of food and environmental temperature. In the psychrometric chamber studies it appears that the animals would be restricted in their movement when compared to animals under field observations. In the latter case, therefore, heat load produced by activity, heat absorbed from solar radiation and metabolic rate has to be got rid of; consequently over a lower air temperature and shorter duration the field animals would produce much more heat, if not equivalent amount to animals shut in a chamber with high temperatures for longer duration. It would appear then that pulse rate is affected by increase in air temperature, more so by solar radiation and exercise. When solar radiation heats the skin it is thought that increased flow of blood to the superficial layers provides some cooling effect. A large volume of blood would be required to bring about this effect and this opportunity appears to be utilized by the response of pulse rate - the harder and faster the beat, the more rapid the flow.

Skin Temperature.

Analy sis of Variance:

Skin temperature data from Table 5 shows highly significant differences for times, days and day x time interaction for the two breeds. According to Findlay and Beakley (1954) increase in air temperature causes increase in skin temperature. At different times throughout the day and on different days differences in skin temperature could be attributed to different weather conditions, particularly solar radiation between and within days. Day x time interaction can also be explained in view of the range in air temperature - the mean difference in air temperature was 24.5°F. and the average range was 57.0°F. - 81.5°F. Although differences in skin temperature does not change as rapidly as air temperature that it does change is shown by Thompson, McCroshery and Brody (1951). However, the range in air temperature experienced was not severe to cause differences between animals. The small differences which appear may be the result of such factors as colour and type of coat. Breed differences were expected to be quite marked but in view of the habits of Berkshires - lying on grass, which did not dry out until almost 2.00 in the afternoon - the difference in skin temperature did not show up.

Components of Variance:

Table of components of variance is remarkably the same for the two breeds with regard to skin temperature. The variance due to animals is negligible for both breeds. Time variance is large for both the breeds, 86% and 83% for Largewhites and Berkshires respectively. Variance due to day is small, approximately 2.5% for both the breeds. The interactions animal x time and animal x day variances are negligible but day x time variance in 9% and 12% for Largewhites and Berkshires respectively. The second order-interaction animal x time x day are both small.

It is apparent from this study that the skin temperature was the direct effect of climate - skin temperature at different times of day coincides with air temperature at that time.

Correlation and Regression Analyses:

Correlation coefficients between air temperature and skin temperature are well-correlated (Table 9). It will be seen that this correlation gave the highest estimates in both breeds. Similar correlation is shown by Patchell (1951) for cattle. As for the other correlations i.e. air temperature with each one of the three variables, rectal temperature, respiration rate and pulse rate, solar radiation seem to show quite a major effect on skin temperature rise. It is difficult to separate solar radiation in this data from air temperature but it would be interesting to set up an experiment under field conditions to study skin temperature in shade and open paddocks simultaneously. In summer, pigs do not have a very dense covering of hair and consequently solar radiation is readily absorbed in the skin of such animals, resulting in gradual rise in skin temperature.

In cattle a one percent rise in air temperature on an average produced 0.31°F. increase in skin temperature (Reimerschmid and Quinlan, 1941; 0.28°F. in the sun and 0.31°F. in the shade). In the pig the regression coefficients given in Table

SKIN TEMPERATURE ~ DIURNAL VARIATION

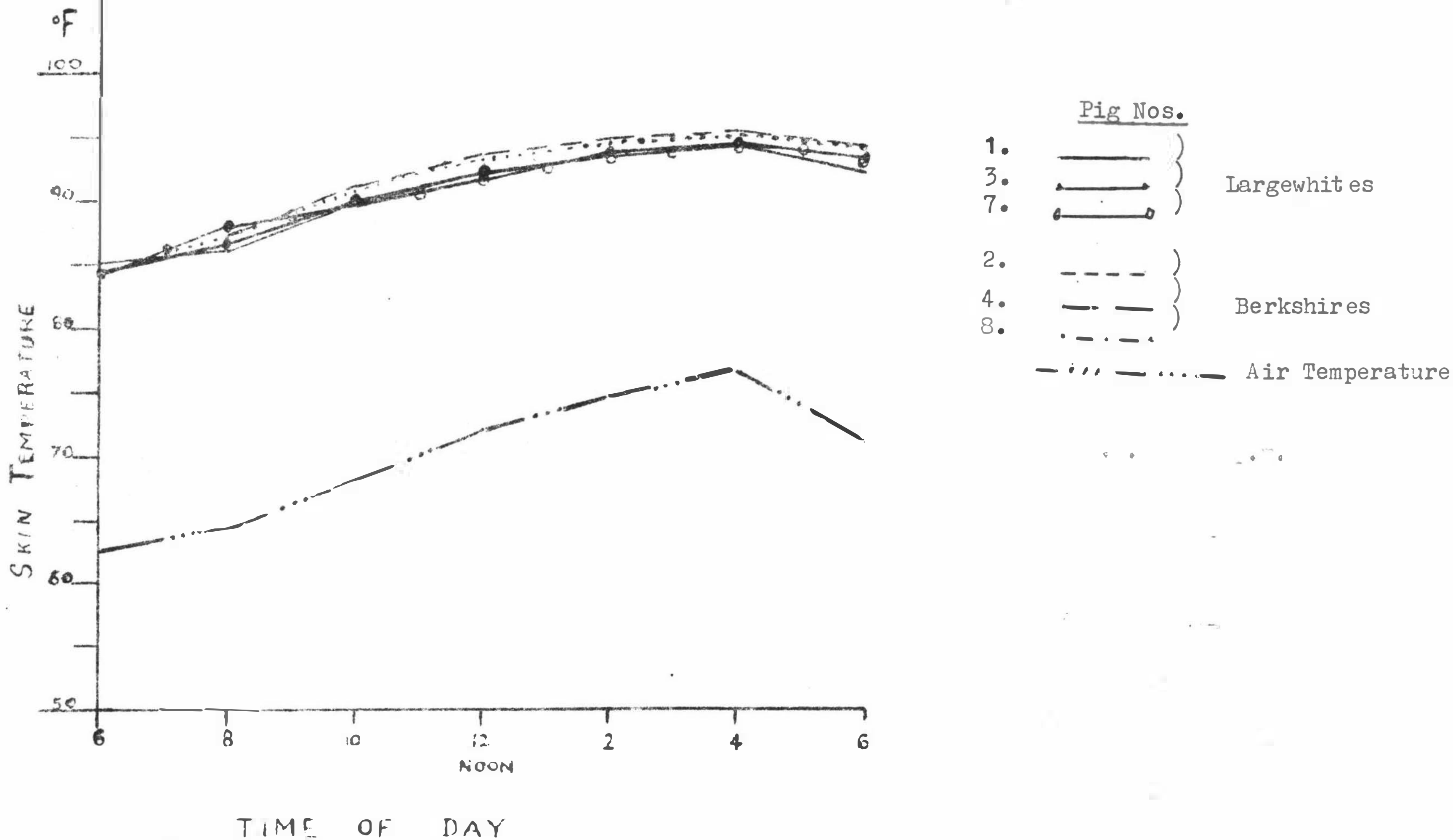


FIGURE V.

indicate an increase of 0.56°F. and 0.57°F. for each degree Fahrenheit rise in air temperature for the Largewhites and the Berkshires respectively. The breed differences were not statistically significant. A significant difference was expected in view of the colour differences between the two breeds. It was thought that black coat colour of the Berkshires would absorb a greater amount of solar radiation. This difference did not appear because of the behaviour of the Berkshires, when the animals were at stress they either lay on the moist grass (dew did not dry out until 12.00 noon) or against the fence line. The animals also "dribbled" in sufficient amounts and they rolled over it or when an animal urinated, others rolled on it. These factors were unavoidable and errors must be considerable due to them.

GRAPHS:

Figure V illustrates the pattern in skin temperature over the daylight period at the time of the experiment. It also shows a gradual rise from 6.00 in the morning until 4.00 in the afternoon, i.e. it coincides with the air temperature.

According to Riemerschmid (1943a) the skin temperature is essentially a result of heat production and heat loss and that these factors are influenced by wide ranges in environmental temperature. Findlay and Beakley (1954) have shown that an increase in air temperature was invariably associated with increase in skin temperature. Wirth (1956) states that skin temperature is dependent partly upon internal body temperature and partly upon the degree of dilation of capillaries. There are also reports suggesting that rise occurs in skin temperatures during exertion; also a local increase occurs in the vicinity of localized inflammation and the underlying tissues.

It will be seen that numerous factors are associated with rise in skin temperature. Factors that cause skin temperature drop are air movement, low level of nutrition, low air temperature, lowered activity, wallowing etc. In this experiment, the pigs were poorly covered with hair at that time. This factor has already been indicated to be disadvantageous when solar radiation was intense; on the other hand such a condition would also be advantageous in the summer for the pigs, provided there was sufficient air movement. That air movement possibly had some effect on skin temperature of the animals is suggested. For this reason differences in the colour did not show up.

BEHAVIOUR OF ANIMALS:

No detailed study was made of the behaviour of individual animals so that only a general discussion of the subject will be reported here.

During the course of the trial the animals showed marked activity from approximately 5.30 in the morning when they heard the pigman or the general noise associated with feeding utensils. They became extremely impatient, some of them stood on their hind legs against the gate while others grunted and paced along the fence in an endeavour to get out. This was principally apparent among the Largewhites as they showed all round general agility. When they were brought in the pen and concentrate fed, they ate greedily, changing their positions in the trough every so often. The Berkshires in general tended to keep the Largewhites away. During feeding the animals frequented the water trough. Feeding lasted approximately ten to fifteen minutes after which the three Berkshires settled down to rest while the Largewhites, expecially no. 7 invariably licked the trough and loafed about. They were all let out of the pen around 7 a.m. in the paddock. Pig no. 7 was always the first to get out and the others followed her. All animals tended to walk to the far end of the paddock first before settling down to graze. The Berkshires grazed close to each other while the Largewhites, especially No. 7, was always furthest away. All animals foraged hard until approximately 10.30 a.m. when first signs of distress began to show up - this distress sign was in the form of increased respiration rate. This accurred on all four days irrespective of air temperature - the highest air temperature recorded at 10.00 a.m. was on the first day with 72^{o}F. and the lowest was 52^{o}F. on the fourth day; surprisingly respiration rate was lower for both breeds on the first day than it was on the fourth day. Berkshires nos. 2 and 8 both were the first to stop grazing. They usually sat down or lay on their sides, getting up from time to time and moving on to new ground. This was interesting in view of the fact that grass was still slightly moist and it appeared that this changing of places resulted in fresh moist grass providing heat loss by way of conduction. By 11.00 a.m. all animals showed disinclination to forage. While the Berkshires lay or sat on the grass the Largewhites paced along the fence line indicating that they sought shelter from the heat of the sun, which the author considered quite intense. Largewhites, it was thought did not settle because of the worry and irritation caused by fly population settling on their sunburnt areas.

At 12.00 noon when all animals were let out of the paddock, the Largewhites raced to shelter under the trees while the Berkshires lazily walked to join them. All animals were very 'frothy' around the mouth. They all lay stretched on their sides and panted hard. Berkshire were not unduly troubled by flies and consequently, remained in one position for the rest of the time. On the other hand, the Largewhites turned over from time to time and flapped their ears regularly to keep flies away.

The animals showed quick relief once they were in the shade, in fact, they showed marked comfort. After 2.00 in the afternoon when they were put out in the paddock for the second time in the day, they again foraged hard, but only for a short time. By 3.15 p.m. they were again in the state of extreme stress. After the 3.30 p.m. measurements, the animals were brought in for their afternoon whey feed which they drank greedily at first and then slowly. Largewhites were the first to settle down. All shivered hard and sat in a crouched posture against the wall of the pen. Berkshire pig no. 2 also showed similar behaviour while Berkshire nos. 4 and 8 stood about the trough. The animals were put out in the paddock again at 4.45 p.m. With the exception of pig. no.7, all others showed disinclination to forage. They lay stretched on their sides. By 6.30 p.m. pig no.7 joined them. She invariably forced herself in the middle of the group. From 8.00 at night, the animals showed practically no activity (except on the fourth day when the air temperature was low, animals did not appear to settle down because Largewhites Pig nos. 1 and 7 and Berkshire pig No. 2 all tried to get into the middle of the group; consequently, disturbing all others) but for urination and to dung which they did away from their sleeping area.

CHAPTER V

Indoors Vs Outdoor Trial.

Introduction.

It has been amply shown in Chapter IV that the sows of the Largewhite and Berkshire breeds under field conditions had a definite diurnal variation in their rectal temperature, respiration rate, pulse rate and skin temperature and that these variables were highly correlated with air temperature. At air temperatures and solar radiations under the conditions of the experiment, the Largewhite and the Berkshire sows showed diurnal variations up to 5.2°F. in rectal temperature, 272 respirations per minute, 116 pulse beats per minute and 7.2°F. in rectal temperature, 189 respirations per minute and 98 pulse beats per minute respectively. The skin temperature variations in the two breeds were not sufficiently large. In view of the large diurnal variation in the three variables it was decided to investigate in more detail the sudden rise between 12.00 noon and 6.00 in the afternoon and the marked drop between 12.00 midnight and 6.00 in the morning.

METHODS AND MATERIALS.

(i) Animals and Animal Management: Twelve adult sows were chosen from the Massey College herd. All animals were in early pregnancy (except Pig No. 12, which had weaned her litter three days prior to the start of the trial) and their liveweights ranged from 410 to 440 lbs. They included two breeds - six Largewhites and six Berkshires.

The twelve test animals were divided into pairs, each pair being made up of a Largewhite and a Berkshire. A sample was aimed at in which the animals in each pair were of as similar liveweight and age as possible. The six pairs were randomly allocated to the two groups.

Group one consisted of the Largewhites 1, 3 and 7 and the Berkshires 2, 4 and 6 were kept indoors in the test house, * the air temperature of which was maintained between 60°F. and 66°F. Group two comprised of Largewhites 7, 9 and 11 and Berkshires 8, 10 and 12 and were on pasture where they were confined to a small area by means of an electric fence unit to prevent them from exerting themselves unnecessarily. In this way it was hoped that any differences between the groups would be due to air temperature and solar radiation. Each animal was fed three times daily at 7.00 a.m. with two pounds of meal (equql parts of barley meal and meat meal), nine pounds of fodder beet at noon and at 6.00 p.m. with approximately one-and-one-half gallons of whey. All pigs were in good health at all times throughout the experiment.

<u>(ii) Measurements and Techniques:</u> Data were obtained on four consecutive test days in early spring between 27th and 31st August.

Rectal temperature, respiration rate and pulse rate were determined for each animal at one hour intervals at 1.15, 2.15, 3.15, 4.15, and 5.15 in the morning and 1.30, 2.30 3.30, 4.30 and 5.30 in the afternoon on each of the four test days. One observation of rectal temperature, three of respiration rates and pulse rates were made at each test time.

Techniques of measurements were similar to those described for the repeatability trial (Chapter III).

Dry and wet bulb temperatures were determined at each test time using a whirling psychrometer.

* A well-insulated house on the Danish style floor plan. It is equipped with air condition unit. This permits air temperature control.

(iii) Treatment of data: From the raw data (Appendix XXXV to XXXVII) it will be observed that the three variables i.e. rectal temperature, respiration rate and pulse rate showed practically identical measurements between the breeds within treatments. Except for Berkshire No. 12, animals within the breeds showed similar responses in their physiological variables to the conditions of the experiment. Consequently all measurements for each pig for each time (a.m. or p.m.) for the four days were pooled together and the means used for the analysis of data.

Data were analysed by means of analysis of variance. Each analysis was of a special time series as outlined by Wilm (1945). This allows the proper testing of some aspects of the analysis by appropriate error or interaction means, but not of others.

TABLE 12.

Range and mean for Air Temperature, Rectal Temperature, Respiration Rate and Pulse Rate - Indoor Vs Outdoor Trial.

	AIR TEMPERATURE °F.		RECTAL TEMPERATURE °F		RESPIRATION RATE Breaths/Min.		PULSE RATE Beats/Min.	
Treatment	IN	OUT	IN	OUT *	IN	OUT	IN	OUT
Range	60-66°	46-65°	100.38-100.60	96.45-102.83	11-28	10-118	68-84	68-120
Mean	64.8	53.5	100.92	100.49	19	52	75	89

* Pig No. 12 registered 104.99°F. and was excluded from the range.

TABLE 13.

TOTAL ANALYSES OF VARIANCE OF RECTAL TEMPERATURE, RESPIRATION RATE AND PULSE RATE - INDOOR Vs. OUTDOOR TRIAL.

		RECTAL TEMP.		RESPIRATION RATE		PULSE RATE	
Source of Variation.	d.f.	M.S.	F.	M.S.	F.	M.S.	F.
Breeds	1	2.20	0.72	7.00	0.74	20.17	1.21
Treatments	1	1.10	0.36	6501.00	0.99	1148.17	1.19
Times	1	48.19	1.92	13968.50	2.13	4213.51	4.38
Breeds x Treatments	1	3.05	0.43	3.10	0.00	16.66	1.80
Breeds x Times	1	0.45	0.00	9.50	0.01	10.66	1.15
Treatments x Times	1	25.12	3.51	6567.00	87.16**	962.66	104.05**
Breeds x Treatments x Times	1	0.08	.001	1.60	0.00	1.54	0.17
ERROR	16	7.15		75.34		9.25	
TOTAL	23						

All F values Not significant unless otherwise shown.

** significant at 1% level.

Results and Discussion.

It was unfortunate that this trial could not be carried out in the summer months because other experiments were in progress at that time in the test house and sufficient suitable animals were not available. The trial was therefore carried out in the following spring. The air temperature at this time of the year was not sufficiently high - in fact, day time temperatures were within the "comfort zone" recommended for pigs by Brody (1945). The intensity of solar radiation was however, high but air movement was also considerable. The night temperatures were low so that the average daily range of air temperatures over the experimental period was 19^{o}F.

Table 12 shows the range and means for each of the three measures together with air temperature.

Table 13 shows the analysis of variance with degrees of freedom, mean squqres and significance for each of the three variables.

Detailed analysis of variance appear in Appendices XXXIX and XXXXI.

RECTAL TEMPERATURE.

From Table 13 it will be seen that rectal temperature differences between breeds, treatments and times were non-significant. The first-order interactions breeds x treatments, breeds x times and treatments x times were also non-significant i.e. all animals in both breeds were similar in their behaviour, irrespective of treatments, breeds and times and their interactions.

From Table 12 it will be seen that the indoor and outdoor animals were maintained at air temperature range of 60^{o}-66^{o}F. and 46^{o} - 65^{o}F. respectively. Brody (1945) gave 21^{o}C. (69.8^{o}F) as the upper limit for the "comfort zone" for all pigs. Heitman and

Hughes (1958) in their most recent publication reported that the zone of thermoneutrality for fattening pigs (liveweights from 100 lb - 350 lb) was between 55° - 75°F. Although the liveweight of sows in the present study were above that of the heaviest pigs in the study made by Heitman and Hughes (1948), it would appear that the 410 lb to 450 lb sows would not be unduly affected by the upper limits in the air temperature experienced under the conditions here. Solar radiation was high but its effect was not very marked in view of the strong air movement. Only Berkshire pig No. 12 showed increased rectal temperature and this was expected since her litter was weaned at three weeks, at which time she was at peak lactation. Throughout the trial she had extremely high rectal temperatures. Lactating cattle have shown higher rectal temperatures and it would be reasonable to assume that lactating sows also have high rectal temperatures. Nevertheless, it will be seen from the raw data (Appendix XXXV) that the outdoor pigs showed higher rectal temperatures than the indoor animals in the afternoon.

The lower limits of the air temperature outdoors was sufficiently severe to lower their rectal temperature. That the animals were not altogether comfortable in pens where air temperature was below 50°F. was shown by numerous workers. Shanks (1942) reported that huddling, fighting and savaging were a common feature when air temperature was dropped from 68°F. to 44°F. Similar behaviour in these animals was observed. In the mornings the outdoor animals showed lowered rectal temperatures. Table 12 shows that the average range in rectal temperature of the outdoor animals was 96.45°F. - 102.83°F. (Pig No. 12 was excluded from this range), a difference of 6.4°F. and the indoor animals showed an average range of 100.38°F. - 100.60°F. a difference of only 0.2°F. Rectal temperature differences were consistent in the indoor groups.

Treatment x times differences were expected to show up due to the intensity of solar radiation but this failed to reach significant level at 5%. This relatively low rectal temperature was considered to be due to strong air movement accompanied by solar radiation. Wind velocity appeared to have had some effect on the ability of the sows in maintaining rectal temperature within narrow limits of normal rectal temperature even when solar radiation was high. Since the animals were confined to a small area, the ground was relatively damp from urination and dung so that the animals kept their body surface relatively moist. That profound cooling effect by increased air motion on animals with "wet" body surfaces was shown by Heitman and Hughes (1948).

(ii) RESPIRATION RATE.

From Table 13 it will be seen that Treatments x times is the only highly significant interaction, all other sources of variation being non-significant.

According to the Missouri school (1953 and 1954) respiratory evaporation in cattle, accounts for up to 30% of the total heat loss but there was a sudden increase in surface evaporation between 65°F - 80°F. In the pig, since its sweat glands are considered to be non-functional, it would appear that the respiratory evaporation is the most important means of heat dissipation (Robinson and Lee, 1941). In the diurnal trial it was shown that diurnal variation did exist in the various physiological variables of the sow and that respiration rate was influenced by such factors as air temperature, solar radiation and the activity of the animal.

In setting up this trial to investigate the effect of air temperature and solar radiation, activity of the animals were cut down to their minimum by enclosing them to a small area.

Unfortunately, another uncontrollable factor crept in so that the differences between the two treatments were solar radiation and wind velocity, the air temperatures outdoors during the day being within limits of the comfort zone of the pig. Psychrometric chamber studies of Heitman and Hughes suggested that rectal temperature was lowered when air movement was increased on "wet" hogs. Respiration rate has been also shown to decrease with rectaltemperature but it is yet to be shown how close a correlation exists between these two variables. The possibility suggests, however, that a slight deviation in the upper limits of the normal rectal temperature range in the pig causes increase in repiration rate. This suggestion is made in view of the suddenness with which the respiration rate is accelerated.

Dukes (1947), suggested that stimulation of afferent fibres in many nerves affect the depth and frequency of respiration. Stimulation of nerve fibres with receptors in the skin, in lightly anaesthetized animals, causes an increase, both in the depth and the rate of breathing. It would appear from the above that skin temperature must influence respiration rate increase markedly. Patchell (1954) has shown a high correlation (r = 0.66) between skin temperature and respiration rate. It is very likely that solar radiation plays an important role in the respiration rate increase by way of increasing skin temperature.

The lower limits in the respiration rate in the morning in the two treatments were the same because of the marked fall in air temperature in the outdoor treatment. This suggests that the respiration rate has a minimum value at rest, unlike the rectal temperature. The air temperature below the "comfort zone" for the pig does not seem to have any marked influence on the respiration rate of the pig.

(iii) PULSE RATE.

This variable showed extremely similar behaviour to respiration rate i.e. only Times x Treatments was highly significant. The between times failed to reach significance level at 5%.

It was suggested in the earlier trials that the pulse rate was an individual characteristic of animals and that such factors as activity, excitement and environmental temperature were the result of marked increase or decrease. From the data in Appendix XXXVII, it will be seen that both treatments showed identical pulse rates in the morning at rest. The pulse rate fell within the normal range of 60-90 beats per minute (Wirth, 1956) for both treatments in spite of the differences in air temperature. Like respiration rate, the lower air temperature does not affect pulse rate when the animal is at complete rest but does so when the animal is active - this is probably psychological more than anything else.

The afternoon measurements showed marked differences between treatments and this was expected in view of the marked increase in respiration rate. In the pig, especially when respiratory evaporation is the main source of heat dissipation a great volume of blood will have to be passed over the respiratory passages to cool the system and this is closely tied up with the increase in pulse rate. Patchell (1954) gave respiration rate and pulse rate r = 0.439. It is difficult to establish the effect of air temperature and/or solar radiation on pulse rate. The findings of Heitman and Hughes (1948) who showed decreased pulse rate with increased air temperature - presumably the high air temperature making the pigs lethargic and consequently cutting down their activity, and by this way, showing decrease in pulse rate - does not hold true when we consider that respiration rate increases with increase in air temperature and respiration and pulse are correlated.

CHAPTER VI

Conclusions and Summary.

The result of a preliminary study showed that, in general, it is possible to achieve a high repeatability of measurements of rectal temperature, respiration rate, pulse rate and skin temperature of the in-pig Largewhites and Berkshire sows kept under normal farm conditions. Rectal temperature and respiration rate estimates were relatively consistent for the two breeds. Pulse rate showed higher repeatability estimate for the Largewhites. The difference between the breeds was difficult to relate to environmentaltemperature conditions since other factors such as excitement, muscular energy, feeding and position were all associated with this variable. Skin temperature measurement on the three positions showed considerable variability and suggests that any one position cannot be used to indicate 'average' skin temperature of sows. Different positions will give different temperatures and the measurements will largely depend on the position of the animals at that particular time.

A study of diurnal variation showed at times that adult dry sows of the Largewhite and Berkshire breeds were under signs of stress and discomfort from heat and cold in view of the large diurnalrange in air temperature - 50.5° - 81.5°F. Rectal temperatures of animals were significantly elevated or lowered by weather conditions. Solar radiation which was high, appeared to be the major contributing factor in causing this eleveation since, when "stressed" animals were sheltered, rectal temperatures showed a marked decrease. At night when animals were at rest and air temperature fell below 50°F., rectal temperature was lowered and the animals huddled together, presumably in order to reduce their effective surface area. In addition, the were restless.

With increase in rectal temperature, respiration rate was also increased. It appeared that there was a definite relationship between rectal temperature elevation and respiration rate rise. Rectal temperature above normal range is suggested as being a major cause of polypnoea. However, a definite rectal temperature at which polypnoea set in, was not established due to individual variation in rectal temperature range. The two breeds showed different behavioural response to heat stress. The Largewhites tended to pace along the fence line indicating that they wought shelter while the Berkshires lay on the moist grass, frequently changing their positions. Exertion thus caused respiration rate rise, was thus evidenced by their behaviour. Berkshires were lethargic and showed disinclination to forage, resulting in lowered respiration rate rise compared to Largewhites which exerted themselves throughout. Position of the animal is of importance in respiration rate measurement since low rates would be obtained if animals were lying. There was a definite minimum value for respiration rate. Lowering the air temperature below 60°F. did not appear to lower respiration rate any further.

Pulse rate was variable although a high correlation with air temperature was obtained. Pulse rate appears to be related to respiration rate but is apparently subject to much greater individual variation than the other variables measured.

Skin temperature measurements were not fully exploited in the trials because of difficulties encountered. The sows tended to lie down on wet surfaces; also some had more hair on than others. Differences between the two breeds were expected in view of the difference in coat colour but these did not appear. However, it was of importance to note that, in spite of slightly lower skin temperature, the Largewhites showed skin burns. The Berkshires, on the other hand, [illegible] did not show any signs of sunburn, indicating that the black skin, in spite of its greater capacity to absorb solar radiation, had some property in the skin structure that prevented sun burn.

The Indoor Vs. Outdoor Trial emphasized the importance of shelter from sunlight and the need to conserve body heat at night when air temperatures were low. Behaviour of the animals of the two breeds showed how some animals (especially the Berkshires 2 and 8) adjusted themselves to conditions better than others - Largewhite No. 7. This latter fact was indicative when we consider how some animals lay on wet surface to keep cool at high ambient air temperatures.

Observations on the four physiological variables are not adequate to draw positive and general conclusions, as only a small number of animals were used in the various experiments.

However, it was sufficient to show that pigs (sows), unlike cattle and sheep are subject both to distress due to heat and and discomfort from cold if proper shelter and/or shade from adverse conditions are not provided. The marked departure in rectal temperature and respiration rate from normal ranges were sufficient evidence to conclude that these sows must expend a great deal of energy in order to maintain the various physiological variables within normal range. With high air temperature and solar radiation they must decrease food intake and thereby reduce production to cut down their internal heat load. For instance, Heitman, Hughes and Kelly (1951) reported that sows pregnant for 85 days or more lost considerable weight when air temperature range was 89.5°F. - 99°F. The litters born to these sows were normal but number of pigs weaned were low. Minnesota Experiments (1937) reported similar results.

With cold, they must increase their intake, the bu of which is used to produce heat for maintenance of their body temperatures, so that loss of production must suffer.

However, under New Zealand management conditions it is not known whether such adverse effects as litter size would be encountered due to high atmospheric temperatures, but cold, damp conditions could cause unthriftiness of young pigs. Further, in New Zealand, hot conditions are not as much a factor as cold, but solar radiation is of considerable importance. The need for protection against the direct effects of sunlight is emphasised. In summer, sprinklers would aid considerably in providing comfort for sows against oppressive conditions. Housing need not be elaborate, but they should be dry and free from draughts. Straw or hay used as bedding should provide sufficient warmth and comfort.

Work of this nature on pigs has not received much attention in New Zealand. The few elaborate pig houses that are found in the country have been constructed on Danish or English plans. These are costly and it is not known whether their construction is justified. Perhaps the pig could perform equally well in a less elaborate house designed to meet local conditions if information on its reaction to such conditions were availabl.e Information on the effect of bulky and cold liquid diet (a feature of New Zealand pig feeding practice) on various classes of pig stock under normal farm conditions, is negligible. Investigation on the effect of pigs kept under corrugated iron roof and on concrete floor - the reflection of solar radiation from which causes oppressive conditions inside their sleeping quarters - needs looking into. Ruakura farrowing houses are becoming popular but in the summer months it is often observed that sows lie outside them. Obviously, the inside gets hot and sultry and must affect the sows and their litters.

These are only a few aspects of the environment as it affects the pig. Information on these are of interest both from economic and scientific points of view.

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RAW DATA FOR DETERMINING REPEATABILITY ESTIMATES.

APPENDIX I.

FIRST DAY.

SKIN TEMPERATURE - RIGHT BELLY.

19th February.

	Pig. No.	a.m. 6.30	a.m. 9.30	p.m. 12.30	p.m. 3.30
LARGEWHITES					
	1	84.50	85.92	92.45	93.95
		88.80	86.26	93.05	94.35
		84.70	88.35	92.50	94.50
	3	90.20	96.40	92.17	93.07
		90.43	96.80	92.19	93.30
		90.52	96.60	92.12	93.09
	5	84.00	96.60	93.45	91.05
		83.61	97.20	92.70	91.30
		83.40	96.70	93.00	91.32
	7	93.65	95.28	92.40	92.40
		94.20	95.56	92.96	92.60
		93.65	95.56	92.68	92.10
BERKSHIRES					
	2	83.50	97.25	95.13	93.95
		84.05	97.80	95.27	94.00
		84.00	97.65	95.19	93.95
	4	89.40	96.95	93.60	92.54
		90.50	97.35	94.00	92.62
		89.70	97.20	94.15	93.40
	6	89.05	99.50	94.70	92.25
		88.80	99.80	94.33	92.90
		89.00	99.20	95.20	92.60
	8	84.95	96.65	95.10	94.90
		85.85	96.78	94.65	95.22
		85.39	96.40	94.90	94.64

APPENDIX II.

SECOND DAY.

SKIN TEMPERATURE - BELLY.

20th February.

	Pig No.	a.m. 6.30	a.m. 9.30	p.m. 12.30	p.m. 3.30
LARGEWHITES	1	85.12	86.90	91.73	93.95
		85.31	86.71	92.90	95.20
		84.97	88.36	93.05	93.60
	3	90.39	91.43	92.91	91.16
		91.40	91.59	93.08	92.13
		90.55	90.88	93.01	92.33
	5	85.19	87.24	94.23	97.29
		85.11	87.61	84.38	97.41
		85.07	87.92	94.71	97.49
	7	91.71	89.77	89.91	91.92
		92.19	89.59	89.71	91.99
		93.90	89.42	88.67	92.93
BERKSHIRES					
	2	84.61	95.23	97.36	95.92
		85.70	97.18	97.91	95.16
		84.90	96.55	95.53	95.80
	4	88.63	90.15	93.31	97.11
		87.55	91.20	94.17	97.18
		89.08	91.39	94.08	96.84
	6	88.73	89.27	90.93	94.90
		88.61	89.33	91.13	94.91
		88.55	89.51	90.88	94.88
	8	84.71	87.18	92.31	93.99
		84.63	87.19	92.63	94.60
		84.81	87.16	91.98	93.68

APPENDIX III.

THIRD DAY.

SKIN TEMPERATURE - BELLY.

21st February.

	Pig No.	a.m. 6.30	a.m. 9.30	p.m. 12.30	p.m. 3.30
LARGE WHITES					
	2	86.55	88.63	89.63	94.60
		86.41	88.69	89.36	94.41
		86.59	88.77	88.89	94.51
	3	87.10	89.21	89.16	96.83
		87.29	89.23	89.19	96.85
		87.23	89.29	89.19	96.85
	5	83.21	88.63	92.71	92.00
		83.22	88.73	92.79	92.10
		83.19	88.73	93.08	92.07
	7	87.22	88.18	89.77	93.61
		88.18	88.23	89.64	93.59
		86.51	88.22	89.63	93.57
BERKSHIRES					
	2	85.77	88.61	93.97	96.91
		85.52	88.68	93.72	96.92
		85.61	88.68	93.76	96.92
	4	86.83	89.50	92.91	95.97
		86.83	89.61	93.61	95.83
		86.88	89.18	92.31	95.87
	6	84.80	85.76	90.61	95.73
		84.88	85.22	91.07	95.51
		84.80	85.22	91.07	95.51
	8	84.23	88.73	90.07	94.34
		84.44	88.73	90.09	94.39
		84.61	88.73	90.13	94.30

APPENDIX IV.

FIRST DAY.

SKIN TEMPERATURE - SHOULDER.

19th February.

		TIME a.m.		p.m.	
	Pig No.	6.30	9.30	12.30	3.30
LARGE WHITES					
	1	81.50	94.58	92.20	93.60
		81.35	94.80	92.35	93.45
		81.20	94.30	92.55	93.00
	3	85.80	93.95	92.00	93.09
		86.82	93.30	91.93	93.05
		86.24	93.35	91.97	93.50
	5	82.93	96.20	91.58	91.80
		83.30	96.07	91.34	91.95
		83.42	96.00	91.75	91.35
	7	84.70	96.40	91.90	92.62
		84.50	97.00	91.45	92.62
		84.55	96.40	91.34	93.00
BERKSHIRES					
	2	80.60	96.75	95.16	92.62
		80.20	96.05	95.27	93.60
		79.85	96.65	95.29	93.00
	4	79.40	95.99	94.94	94.60
		79.85	95.95	94.30	94.48
		80.30	95.95	94.50	94.35
	6	88.90	99.22	95.60	93.07
		89.61	98.94	96.00	93.45
		89.00	98.60	96.40	93.25
	8	80.28	98.88	94.90	94.35
		79.40	98.48	94.94	94.32
		80.15	99.02	95.40	94.45

APPENDIX V.

SECOND DAY.

SKIN TEMPERATURE - SHOULDER.

20th February.

		TIME			
		a.m.		p.m.	
	Pig. No.	6.30	9.30	12.30	3.30
LARGEWHITES					
	1	82.73	94.58	95.50	94.10
		82.66	95.21	94.20	94.29
		82.70	95.33	95.70	94.78
	3	84.31	86.80	88.77	90.00
		85.40	86.80	89.43	90.08
		85.60	88.30	88.79	89.60
	5	87.13	88.29	90.71	93.68
		86.92	88.49	90.63	93.64
		87.32	88.56	90.59	93.59
	7	86.80	87.93	88.23	93.13
		86.89	87.61	88.29	94.77
		87.33	87.43	88.23	94.31
BERKSHIRES					
	2	82.80	96.70	98.20	98.71
		83.32	96.98	98.96	98.20
		82.96	99.73	96.71	98.05
	4	83.90	94.42	95.09	96.91
		84.20	94.59	95.60	96.72
		84.33	93.19	95.37	96.55
	6	86.03	88.30	99.22	96.41
		86.63	88.39	99.44	96.55
		87.03	88.71	89.08	96.53
	8	86.77	89.29	93.30	94.16
		86.78	89.26	93.18	95.51
		86.24	89.81	94.22	95.23

APPENDIX VI.

THIRD DAY.

SKIN TEMPERATURE - SHOULDER.

21st February.

		TIME			
		a.m.		p.m.	
	Pig No.	6.30	9.30	12.30	3.30
LARGEWHITES					
	1	84.10	87.41	93.22	97.31
		84.10	87.19	93.27	97.33
		84.10	87.15	93.27	97.38
	3	84.87	88.73	92.31	97.21
		84.41	88.73	92.36	97.33
		84.88	88.79	92.35	97.38
	5	83.71	88.73	94.23	96.97
		83.66	88.76	94.31	96.92
		83.59	88.74	94.77	96.90
	7	86.53	90.41	95.17	95.33
		86.66	90.53	95.33	95.38
		86.18	90.71	95.47	94.92
BERKSHIRES					
	2	84.33	86.71	92.71	97.38
		84.71	86.61	91.89	97.38
		84.38	86.73	92.51	97.38
	4	85.80	88.80	94.22	96.95
		85.90	88.82	94.27	96.92
		84.89	88.80	94.29	96.91
	6	85.21	89.29	93.77	95.43
		85.91	89.31	93.79	95.51
		83.93	89.22	93.91	95.59
	8	84.13	90.09	94.51	95.56
		84.18	90.00	94.55	95.73
		74.23	90.23	94.58	95.71

APPENDIX VII.

FIRST DAY.

SKIN TEMPERATURE - RUMP.

19th February.

	Pig no.	a.m. 6.30	a.m. 9.30	p.m. 12.30	p.m. 3.30
LARGEWHITES					
	1	80.25	93.90	91.80	92.90
		80.60	94.25	91.30	93.05
		79.81	93.50	91.40	92.65
	3	79.20	93.35	91.78	93.75
		79.28	93.20	91.73	94.30
		79.25	93.07	91.77	93.67
	5	83.64	96.00	91.70	91.65
		83.64	95.90	90.50	91.60
		83.20	95.60	91.20	91.59
	7	84.95	97.16	90.92	93.35
		85.30	96.40	91.34	92.70
		84.95	97.06	91.10	92.65
BERKSHIRES					
	2	79.80	96.15	95.03	93.05
		80.20	96.20	95.09	93.85
		79.30	95.95	95.11	93.45
	4	80.20	95.60	93.07	94.35
		80.25	95.98	93.45	94.40
		80.20	95.94	98.50	94.49
	6	85.38	98.82	96.00	93.50
		80.59	98.20	94.65	93.93
		80.20	97.79	94.94	94.50

APPENDIX VIII.

SECOND DAY.

SKIN TEMPERATURE - RUMP.

20th February.

	Pig. No.	TIME a.m. 6.30	9.30	p.m. 12.30	3.30
LARGEWHITES	1	80.25	93.22	92.93	92.00
		80.30	93.26	92.92	93.75
		80.27	93.80	92.92	93.00
	3	84.18	85.89	87.80	89.70
		84.23	85.92	87.89	89.73
		84.23	85.88	87.86	89.69
	5	87.89	88.84	91.25	97.77
		87.83	88.17	91.20	97.79
		87.88	88.33	91.20	97.78
	7	87.63	88.82	89.22	92.30
		87.55	88.77	89.19	92.25
		87.59	88.79	89.29	92.29
BERKSHIRES					
	2	81.95	95.12	95.73	96.77
		82.05	95.18	95.90	96.79
		81.98	95.33	95.88	96.58
	4	83.21	95.18	95.33	96.98
		83.29	95.30	95.36	97.00
		83.31	95.22	95.39	96.97
	6	86.19	90.09	94.63	96.54
		86.11	90.22	94.41	96.52
		86.11	90.17	94.49	96.59
	8	87.23	89.55	94.30	85.45
		87.23	89.49	94.31	85.40
		87.24	89.52	94.38	95.39

APPENDIX IX.

THIRD DAY.

SKIN TEMPERATURE - RUMP.

21st February.

	Pig No.	6.30 a.m.	9.30 a.m.	12.30 p.m.	3.30 p.m.
LARGEWHITES	1	85.81	87.59	94.23	97.28
		85.81	87.49	94.11	97.28
		95.88	87.59	94.18	97.28
	3	86.91	90.53	94.29	97.61
		86.91	90.59	94.27	97.68
		86.95	90.59	94.33	97.65
	5	83.71	88.80	93.08	97.29
		83.73	88.83	93.08	97.19
		83.70	86.84	93.11	97.17
	7	87.18	90.72	96.33	96.95
		87.18	90.79	96.35	96.89
		87.18	90.76	96.33	96.91
BERKSHIRES					
	2	85.17	86.91	93.31	99.93
		85.14	86.94	93.39	99.93
		85.15	87.00	93.37	99.96
	4	86.63	89.53	95.08	97.03
		86.62	89.54	95.04	97.05
		86.69	89.47	95.55	97.05
	6	84.86	91.73	95.27	96.79
		84.91	91.73	95.23	96.73
		84.88	91.79	94.31	96.73
	8	84.13	89.32	94.44	98.16
		84.18	89.32	94.44	98.16
		84.18	91.16	94.47	98.16

APPENDIX X

REPEATABILITY - RECTAL TEMPERATURE

		LARGEWHITES				BERKSHIRES			
Source of Variation	d.f.	S.S.	M.S.	F	Result	S.S.	M.S.	F	Result
A	3	12.20	4.07	0.84	N.S.	10.60	3.53	3.04	N.S.
T	3	74.20	24.73	5.13	*	218.10	72.70	62.67	**
D	3	4.70	1.57	0.73	N.S.	48.90	16.30	12.44	**
AxT	9	43.40	4.82	3.05	*	10.50	1.16	0.73	N.S.
AxD	9	5.56	0.62	0.39	N.S.	5.49	0.61	0.38	N.S.
DxT	9	19.27	2.14	1.35	N.S.	11.81	1.31	0.83	N.S.
AxTxD	27	42.57	1.58	17.00	**	42.40	1.57	31.00	**
Readings	128	11.90	0.093			1.57	0.012		
TOTAL	191	213.80				349.37			

REPEATABILITY - RESPIRATION RATE

APPENDIX XI

		LARGEWHITES				BERKSHIRES			
Source of Variation	d.f.	S.S.	M.S.	F	Result	S.S.	M.S.	F	Result
A	3	2419.00	806.32	1.15	N.S.	2234.00	744.67	1.24	N.S.
T	3	48235.00	16078.33	5.16	*	37009.00	12336.33	5.64	*
D	3	7178.30	2059.43	0.66	N.S.	17241.20	5747.06	2.63	N.S.
AxT	9	6318.00	702.30	0.63	N.S.	5412.00	601.33	1.32	N.S.
AxD	9	20603.70	2279.30	2.06	N.S.	2188.46	232.05	0.51	N.S.
DxT	9	28064.40	3118.27	2.82	*	19696.30	2188.46	4.79	**
AxDxT	27	29887.20	1106.99	427.41	**	12327.24	456.56	125.77	**
Readings	128	331.40	2.59			464.00	3.63		
TOTAL	191	143037.20				96572.20			

N.S. = Non-significant.

* = Significant at 5% level.

** = Significant at 1% level.

APPENDIX XII

REPEATABILITY - PULSE RATES

Source of Variation	d.f.	LARGEWHITES S.S.	LARGEWHITES M.S.	LARGEWHITES F	LARGEWHITES Result	BERKSHIRES S.S.	BERKSHIRES M.S.	BERKSHIRES F	BERKSHIRES Result
A	3	950.00	316.78	0.89	N.S.	4714.70	1571.57	3.21	N.S.
T	3	3535.00	1178.33	3.30	N.S.	3129.70	1043.23	2.13	N.S.
D	3	2653.00	884.33	1.44	N.S.	302.90	100.97	0.18	N.S.
AxT	9	3216.00	357.33	1.79	N.S.	4400.60	488.96	0.70	N.S.
AxD	9	3164.00	351.56	1.76	N.S.	3829.10	425.46	0.61	N.S.
DxT	9	5531.70	614.63	3.07	*	5028.80	558.76	0.80	N.S.
AxDxT	27	5400.30	200.11	38.12	**	18787.50	695.83	15.28	**
Readings	128	672.00	5.25			5831.00	45.55		
TOTAL	191	25122.00	131.53			46024.30			

N.S. = Non⅜significant.
* = Significant at 5% level.
** = Significant at 1% level.

APPENDIX XIII

REPEATABILITY - SKIN TEMPERATURE

LARGEWHITES

		POSITIONS											
		BELLY				SHOULDER				RUMP			
Source of Varia-tion	d.f.	S.S.	M.S.	F	Res-ult	S.S.	M.S.	F	Res-ult	S.S.	M.S.	F	Res-ult
A	3	96.70	32.23	0.76	N.S.	21.00	7.00	0.61	N.S.	52.50	17.50	2.28	N.S.
T	3	717.30	239.10	5.64	*	1813.30	604.43	52.79	**	1915.30	638.43	83.24	**
D	3	98.90	49.45	1.47	N.S.	51.90	25.95	0.35	N.S.	158.90	79.45	0.95	N.S.
AxT	9	380.90	42.32	2.93	*	103.02	11.45	2.83	*	68.92	7.67	0.34	N.S.
AxD	6	63.09	10.52	0.72	N.S.	17.30	2.88	0.71	N.S.	133.78	22.29	1.42	N.S.
DxT	6	201.86	33.64	2.32	N.S.	432.80	72.13	17.85	**	502.31	83.72	5.33	**
AxDxT	18	260.18	14.45	80.28	**	72.80	4.04	40.40	**	283.19	15.72	15.89	**
Read-ings	96	17.41	0.18			9.66	0.10			95.10	0.99		
TOTAL	143	1836.64				2521.78				3210.00			
Repeatability		0.96				0.93				0.83			

N.S. = Non-significant.
* = Significant at 5% level.
** = Significant at 1% level.

APPENDIX XIV

REPEATABILITY - SKIN TEMPERATURE

BERKSHIRES

		BELLY				SHOULDER				RUMP			
Source of Variation	d.f.	S.S.	M.S.	F	Result	S.S.	M.S.	F	Result	S.S.	M.S.	F	Result
A	3	83.70	27.90	1.95	N.S.	26.00	8.66	0.65	N.S.	19.60	6.53	0.97	N.S.
T	3	1485.00	495.00	34.51	**	3221.90	1073.96	77.15	**	3229.00	1076.33	159.93	**
D	2	213.20	106.60	1.36	N.S.	87.30	43.65	0.51	N.S.	1.90	0.63	0.09	N.S.
AxT	9	129.02	14.34	1.95	N.S.	119.59	13.29	0.90	N.S.	60.53	6.73	0.68	N.S.
AxD	6	86.30	14.38	1.96	N.S.	127.16	21.19	1.44	N.S.	59.58	9.93	1.31	N.S.
DxT	6	471.50	78.58	10.69	**	513.57	85.59	5.81	**	555.54	92.59	12.22	**
AxDxT	18	132.22	7.35	49.00	**	265.36	14.74	7.05	**	136.45	7.58	9.97	**
Readings	96	14.60	0.15			201.31	2.09			72.93	0.76		
TOTAL	143	2615.54				4562.19				4235.53			
Repeatability		0.94				0.67				0.75			

N.S. = Non-significant.

* = Significant at 5% level.
** = Significant at 1% level.

APPENDIX XV

LARGEWHITES

* Components of variance derived from analysis of variance for rectal temperature, respiration and pulse rates.

Source of Variation	Rectal Temperature		Respiration Rate		Pulse Rate	
	Actual	%	Actual	%	Actual	%
Animal						
Times	0.41	19.71	270.00	30.31	21.18	13.75
Days					2.46	1.59
Animals x Times					13.02	8.45
Animals x Days			90.08	10.11	12.62	8.19
Days x Times			160.08	17.97	34.54	22.42
Animals x Days x Times	1.58	75.96	368.13	41.32	64.95	42.17
Readings	0.093	4.36	2.59		5.25	3.41
TOTAL	2.08		890.88		154.02	
Repeatability	0.84		0.99		.93	

* Only positive values are given.

APPENDIX XVI

BERKSHIRES

*Components of variance derived from analysis of variance for rectal temperature, respiration and pulse rates.

Source of Variation	Rectal Temperature		Respiration Rate		Pulse Rate	
	Actual	%	Actual	%	Actual	%
A	18.32	5.35	2.98	0.49	19.19	6.65
T	4.55	1.33	208.40	34.97	7.24	2.51
D			74.14	12.43		
A x T	18.89	5.51	12.05	2.02		
A x D	13.60	3.97				
D x T	24.70	7.21	144.32	24.19		
A x D x T	216.77	63.31	150.98	25.32	216.77	75.01
Readings	45.55	13.30	3.63	0.61	45.55	15.77
TOTAL						
Repeatability	0.83		0.98		0.83	

* Only positive values are given.

APPENDIX XVII

SKIN TEMPERATURE

		LARGEWHITES						BERKSHIRES					
		Belly		Shoulder		Rump		Belly		Shoulder		Rump	
Source of Variation	d.f	Actual	%	Actual	%	Actual	%	Actual	%	Actual	%	Actual	%
A	3								0.18	0.88			
T	3	4.85	32.37	14.58	64.12	16.92	61.00	11.39	52.10	29.31	56.97	27.33	72.78
D	2	0.27	3.00			0.09	.30	0.44	2.01	14.97	29.09		
AxT	9	3.08	20.56	0.82	4.00			0.77	3.52				
AxD	6					0.55	2.00	0.59	2.70	0.54	1.05	0.11	0.30
DxT	6	1.84	12.28	5.66	25.19	4.43	15.80	5.94	27.17	0.32	0.62	7.08	18.85
AxDxT	18	4.76	31.78	1.31	5.80	4.91	17.60	2.40	10.98	4.22	8.22	2.27	6.05
Readings	96	0.18	1.0	0.10	0.50	0.99	3.80	0.15	0.69	2.09	4.06	0.76	2.0
TOTAL	143	14.98		22.47		27.88		21.86		51.45		37.55	

Positive values are only given.

R A W   D A T A   F O R

D I U R N A L   V A R I A T I O N

T R I A L.

APPENDIX XVIII

RECTAL TEMPERATURE - °F.

	TIME / Pig No.	8.00	10.00	Mid-night 12.00	2.00	4.00	6.00	8.00	10.00	Noon 12.00	2.00	3.30	4.15	6.00
LARGEWHITES														
	1	101.50	100.88	99.40	99.00	98.33	98.73	97.50	101.53	102.80	102.60	104.60	102.85	102.72
First Day	3	101.50	100.62	99.98	99.53	100.40	99.40	98.21	100.62	104.60	103.77	105.63	103.87	103.87
	7	100.97	100.45	99.98	98.90	98.55	99.00	98.78	101.27	103.45	102.77	103.87	103.42	102.02
BERKSHIRES														
4.3.58	2	99.72	99.33	99.23	98.70	97.28	97.35	97.12	100.65	104.43	103.21	104.10	103.53	102.52
	4	101/50	100.75	100.87	100.50	100.33	100.55	99.80	103.23	104.42	103.62	105.35	102.42	101.70
	8	101.30	100.60	100.30	100.23	100.80	100.20	100.02	100.12	104.53	103.62	104.32	104.53	102.90
LARGEWHITES														
	1	102.05	100.33	100.23	96.73	97.52	99.70	101.50	101.55	102.60	103.60	104/30	103.30	102.20
Second Day	3	102.03	101.33	99.78	99.90	99.82	101.40	101.60	102.08	102.33	103.72	103.95	102.93	102.80
	7	101.72	101.12	100.80	100.20	99.23	99.68	100.93	101.10	101.35	102.23	103.85	103.10	102/02
BERKSHIRES														
6.3.58	2	101.50	100.57	99.92	99.05	97.05	101.50	101.78	101.40	102.52	102.72	102.92	102.63	102.21
	4	101.30	100.20	100.05	99.02	97.05	98.60	100.70	101.10	103.02	103.40	104.33	103.70	102.93
	8	102.20	101.78	100.47	100.38	98.42	99.85	100.50	101.02	102.02	102.90	103.52	102.70	102.52
LARGEWHITES														
	1	101.65	100.30	100.25	99.13	98.98	100.62	100.73	101.63	102.21	102.10	102.33	101.98	102.30
Third Day	3	102.80	101.85	100.22	100.05	99.80	101.30	101.63	102.20	102.20	101.63	101.95	101.21	102.40
	7	101.63	100.55	99.72	98.43	98.33	100.53	100.95	101.20	102.85	100.90	101.70	101.72	102.52
BERKSHIRES														
9.3.58	2	101.50	99.92	98.80	97.05	97.00	99.60	100.25	101.02	102.98	101.55	102.48	102.12	102.20
	4	100.97	100.02	100.03	98.92	98.83	99.66	100.90	101.07	101.95	101.40	101.70	101.58	101.58
	8	101.03	100.50	100.48	99/63	99.55	99.58	100.73	101.37	101.95	100.08	101.60	101.75	102.50
LARGEWHITES														
	1	101.10	99.12	99.02	99.00	96.23	99.92	100.92	101.60	103.32	102.06	102.63	103.02	101.32
Fourth Day	3	102.40	99.58	97.30	96.30	97.43	98.11	101.30	101.48	103.80	102.61	102.68	103.20	100.40
	7	101.50	99.77	97.33	97.23	100.07	100.45	100.55	100.77	101.40	100.95	100.68	102.05	101.73
BERKSHIRES														
11.3.58	2	99.20	98.00	98.05	98.06	97.60	97.03	99.83	100.97	104.60	102.48	103.35	103.00	100.66
	4	101.32	99.61	98.88	98.25	99.02	99.08	100.27	101.70	103.57	102.27	102.35	102.03	101.20
	8	100.88	100.30	99.82	99.57	99.33	99.12	101.30	101.85	103.67	101.72	102.33	102.02	101.03

APPENDIX XIX

RESPIRATION RATE (Beats/Min.)

Pig No.	8.00	10.00	Mid-night 12.00	2.00	4.00	6.00	8.00	10.00	12.00	2.00	3.30	4.15	6.00
LARGEWHITES													
1	22	18	16	14	10	24	24	49	135	163	171	57	31
3	34	18	14	15	12	32	44	56	142	166	171	69	75
7	19	18	18	17	12	28	24	45	125	181	194	179	24
4.3.58													
BERKSHIRES													
2	33	13	14	14	11	21	32	48	143	131	165	64	120
4	26	18	18	16	12	28	32	72	174	161	197	64	43
8	24	21	18	18	15	26	41	61	171	167	173	87	55
LARGEWHITES													
1	24	14	12	10	9	20	28	56	108	129	159	72	37
3	28	12	12	11	12	32	25	56	181	159	191	96	55
7	24	12	11	11	11	24	32	36	171	181	184	116	25
6.3.58													
BERKSHIRES													
2	37	24	16	12	9	24	33	57	153	143	163	81	32
4	32	14	12	10	12	24	30	40	138	135	136	81	36
8	33	16	16	12	8	24	36	64	112	127	139	84	48
LARGEWHITES													
1	14	11	12	10	9	34	36	87	98	96	56	38	57
3	13	13	13	12	12	34	44	94	112	75	65	56	45
7	14	14	12	11	11	33	48	124	136	48	81	48	29
9.3.58													
BERKSHIRES													
2	14	11	12	11	10	32	32	56	112	43	68	37	43
4	14	13	12	11	11	37	48	65	103	64	72	36	48
8	14	14	12	10	9	29	48	85	102	72	68	48	32
LARGEWHITES													
1	16	12	11	11	10	13	28	73	145	88	107	53	24
3	13	12	12	11	11	12	37	114	233	113	152	64	20
7	15	16	14	13	11	12	32	128	281	85	85	65	25
11.3.58													
BERKSHIRES													
2	16	12	12	12	10	13	24	100	72	143	122	56	23
4	27	14	13	12	11	15	24	105	153	141	112	46	21
8	14	12	11	12	10	12	28	87	163	89	92	52	35

APPENDIX XX

PULSE RATE (Beats/Min.)

TIME Pig No.	8.00	10.00	Mid-night 12.00	2.00	4.00	6.00	8.00	10.00	12.00	2.00	3.30	4.15	6.00
LARGEWHITES													
1	72	62	60	55	54	52	87	97	113	113	118	101	88
3	77	68	68	64	60	60	80	96	111	105	116	99	93
7	73	72	68	60	60	56	70	104	121	102	119	105	88
4.3.58													
BERKSHIRES													
2	64	64	60	56	60	58	66	88	125	101	106	97	88
4	97	79	78	76	71	68	75	109	123	122	133	104	91
8	73	72	68	60	60	56	70	104	121	102	119	105	88
LARGEWHITES													
1	76	80	72	73	76	88	88	88	104	133	163	122	94
3	77	74	74	68	64	80	80	91	144	149	116	128	123
7	83	76	72	72	70	76	88	81	100	151	168	119	93
6.3.58													
BERKSHIRES													
2	80	80	72	71	64	80	87	96	128	127	151	96	93
4	92	88	84	84	84	88	88	96	116	121	136	96	96
8	76	76	72	72	68	87	84	92	104	120	136	101	96
LARGEWHITES													
1	76	76	73	70	67	76	87	112	123	95	84	84	88
3	82	74	72	72	71	84	96	117	124	102	92	88	96
7	96	86	80	74	70	87	93	104	125	104	88	88	104
9.3.58													
BERKSHIRES													
2	85	76	68	68	67	64	84	104	107	112	84	72	96
4	83	79	73	68	65	79	95	104	111	93	96	79	112
8	80	76	72	68	64	72	88	94	96	98	96	73	73
LARGEWHITES													
1	93	84	76	76	68	72	99	128	125	93	104	101	96
3	84	74	72	76	68	76	80	120	103	103	96	91	90
7	84	80	83	71	73	79	104	123	122	95	97	97	97
11.3.58													
BERKSHIRES													
2	88	86	80	76	76	72	88	99	113	103	93	89	100
4	86	84	80	80	80	80	81	91	123	120	104	94	100
8	80	76	72	71	64	61	73	113	124	103	96	93	84

APPENDIX XXI

SKIN TEMPERATURE - °F.

	Pig No.	6.00 a.m.	8.00 a.m.	10.00 a.m.	12.00 Noon	2.00 p.m.	4.00 p.m.	6.00 p.m.
LARGEWHITES								
First day Feb.	1	85.90	86.04	87.53	89.68	93.30	93.88	91.28
	3	85.82	85.95	85.97	89.37	93.87	93.88	91.42
	7	84.69	85.34	85.90	87.51	93.17	93.84	91.45
26.2.58 **BERKSHIRES**								
	2	84.86	85.10	88.99	90.48	93.74	94.65	91.53
	4	83.56	84.88	89.36	90.57	93.62	94.10	92.65
	8	84.39	84.43	88.54	90.44	94.19	94.86	93.69
LARGEWHITES								
Second day Feb.	1	85.80	87.06	93.32	94.36	94.78	94.66	93.56
	3	84.29	85.70	93.54	94.38	95.11	94.77	93.91
	7	84.50	84.89	93.69	94.57	95.38	94.99	93.68
2.3.58 **BERKSHIRES**								
	2	84.53	85.12	94.93	95.75	96.40	95.72	93.59
	4	83.45	85.98	94.09	94.78	95.49	94.76	93.79
	8	84.49	84.58	94.58	95.53	95.61	94.97	94.25
LARGEWHITES								
Third day Feb.	1	83.97	86.30	90.22	94.42	93.92	94.39	93.53
	3	83.88	86.30	87.58	94.44	93.90	94.43	93.74
	7	84.22	86.36	87.91	94.57	93.93	94.40	93.64
13.3.58 **BERKSHIRES**								
	2	84.98	89.19	90.71	95.53	93.85	95.24	93.90
	4	84.86	87.57	90.92	94.90	93.93	94.92	93.92
	8	84.80	88.76	90.78	95.39	94.24	95.73	93.54
LARGEWHITES								
Fourth day Feb.	1	84.93	85.09	87.77	89.99	92.22	93.69	93.05
	3	85.04	88.69	88.95	90.04	91.55	93.45	92.84
	7	85.11	85.88	89.18	90.65	93.21	94.00	92.60
16.3.58 **BERKSHIRES**								
	2	84.32	88.95	88.79	90.68	93.24	94.10	93.27
	4	84.41	85.89	89.49	90.97	93.80	94.29	92.82
	8	84.28	84.92	89.76	91.26	92.52	94.34	93.57

APPENDIX XXII

AIR TEMPERATURE - °F.

TIME Pig No.	8.00	10.00	Mid-night 12.00	2.00	4.00	6.00	8.00	10.00	Noon 12.00	2.00	3.30	4.15	6.00
4.3.58													
D.B	65.5	65.0	63.5	63.5	65.0	64.5	65.3	72.5	75.0	77.0	78.5	75.0	70.0
W.B.	63.5	63.0	61.0	62.0	63.0	62.5	63.5	69.0	70.0	69.0	74.0	67.5	65.0
6.3.58													
D.B.	66.5	66.0	65.5	60.0	63.5	65.0	68.0	69.0	75.0	79.0	81.5	78.0	75.0
W.B.	63.0	60.5	60.5	52.0	50.0	54.0	64.0	65.0	69.0	66.0	70.5	68.5	68.0
9.3.58													
D.B.	63.0	60.0	62.5	60.5	61.0	61.5	65.0	70.63	77.0	70.5	73.0	72.0	70.0
W.B.	61.0	57.5	60.5	58.5	59.0	60.0	61.0	53.0	65.0	65.0	65.0	66.0	63.0
11.3.58													
D.B.	55.0	51.0	51.0	53.5	51.5	52.0	50.5	52.0	69.0	73.0	75.2	75.2	69.8
W.B.	49.0	50.0	47.0	46.5	46.5	46.5	46.5	49.0	60.0	64.0	65.0	69.0	65.0

APPENDIX XXIII

DIURNAL VARIATION - RECTAL TEMPERATURE.

LARGEWHITES.

Source of Variation	d.f.	S.S.	M.S.	F	Results
A	2	6.80	3.40	7.39	**
T	12	352.70	29.39	15.15	**
D	3	18.60	6.20	3.19	*
A x T	24	11.10	0.46	0.63	N.S.
A x D	6	2.16	0.36	0.49	N.S.
D x T	36	69.88	1.94	2.66	**
A x T x D	72	52.56	0.73		
TOTALS	155	503.80			

APPENDIX XXIV

DIURNAL VARIATION - RECTAL TEMPERATURE.

BERKSHIRES.

Source of Variation	d.f.	S.S.	M.S.	F	Results
A	2	0	0		N.S.
T	12	377.30	31.44	20.68	**
D	3	17.80	5.93	1.67	N.S.
A x T	24	3.10	0.13	0.19	N.S.
A x D	6	21.30	3.55	5.14	**
D x T	36	54.81	1.52	2.20	**
A x T x D	72	50.31	0.69		
TOTALS	155	524.62			

N.S. = not significant;
* = significant at 5% level;
** = significant at 1% level.

APPENDIX XXV

DIURNAL VARIATION - RESPIRATION RATES.

LARGEWHITES.

Source of Variation	d.f.	S.S.	M.S.	F	Results
A	2	4028.00	2014.0	4.46	*
T	12	386897.00	32241. 42	15.74	**
D	3	8019.10	2673.03	1.30	N.S.
A x T	24	10838.00	451.58	1.58	N.S.
A x D	6	802.20	133.70	0.47	N.S.
D x T	36	73762.65	2048.96	7.19	**
A x T x D	72	20520.15	285.00		
TOTALS	155	380216.0			

APPENDIX XXVI

DIURNAL VARIATION - RESPIRATION RATES.

BERKSHIRES.

Source of Variation	d.f.	S.S.	M.S.	F	Results
A	2	12.00	6.00		N.S.
T	12	314204.00	26188.67	23.29	**
D	3	13052.20	4350.73	3.87	*
A x T	24	2057.00	85.71	0.66	N.S.
A x D	6	1058.80	176.47	1.35	N.S.
D x T	36	40464.80	1124.02	8.63	**
A x D x T	72	9367.20	130.23		
TOTALS	155				

N.S. = not significant.
* = significant at 5% level.
** = significant at 1% level.

APPENDIX XXVII

DIURNAL VARIATION - PULSE.

LARGEWHITES.

Source of Variation	d.f.	S.S.	M.S.	F	Results
A	2	79.00	39.50	0.31	N.S.
T	12	51678.50	4306.54	8.92	**
D	3	3960.40	1320.13	2.74	N.S.
A x T	24	578.30	24.09	0.43	N.S.
A x D	6	752.60	125.43	2.23	*
D x T	36	17325.40	481.26	8.57	**
A x D x T	72	4045.80	56.15		
TOTALS	155				

APPENDIX XXVIII

DIURNAL VARIATION - PULSE.

BERKSHIRES.

Source of Variation	d.f.	S.S.	M.S.	F	Results
A	2	1763.60	881.80	6.66	**
T	12	39800.00	3316.66	12.48	**
D	3	2355.10	785.03	2.95	N.S.
A x T	24	764.40	3185.	2.14	*
A x D	6	794.80	132.47	8.92	**
D x T	36	9565.10	265.70	17.88	**
A x T x D	72	1070.00	14.86		
TOTALS	155	56113.00			

N.S. = not significant.
* = significant at 5% level.
** = significant at 1% level.

APPENDIX XXIX

DIURNAL VARIATION - SKIN TEMPERATURES.

LARGEWHITES.

Source of Variation	d.f.	S.S.	M.S.	F	Results
A	2	0.50	0.25	0.34	N.S.
T	6	1010.00	168.33	26.63	**
D	3	71.10	23.70	3.75	**
A x T	12	3.90	0.33	0.75	N.S.
A x D	6	4.40	0.73	1.66	N.S.
D x T	18	113.80	6.32	14.36	**
A x T x D	36	15.70	0.44		
TOTALS	83	1219.40			

APPENDIX XXX

DIURNAL VARIATION - SKIN TEMPERATURES.

BERKSHIRES.

Source of Variation	d.f.	S.S.	M.S.	F	Results
A	2	1.30	0.65	1.16	N.S.
T	6	1202.80	200.47	37.97	**
D	3	70.20	23.40	4.43	**
A x T	12	6.70	0.56	1.51	N.S.
A x D	6	1.00	0.17	0.46	N.S.
D x T	18	95.00	5.28	14.27	**
A x T x D	36	13.50	0.37		
TOTALS	83	1390.50			

N.S. = not significant.
* = significant at 5% level.
** = significant at 1% level.

APPENDIX XXXI

Correlation coefficients between the air temperature and the rectal temperature.

Correlation coefficients.

	DAYS	1	2	3	4	TOTALS
	Pigs					
LARGEWHITES	1	0.69**	0.91**	0.85**	0.73**	0.66**
	3	0.87**	0.92**	0.49(N.S)	0.67**	0.73**
	7	0.91**	0.87**	0.40(N.S)	0.55*	0.59**
BERKSHIRES	2	0.95**	0.80**	0.82**	0.85**	0.76**
	4	0.95**	0.92**	0.88**	0.78**	0.76**
	8	0.91**	0.83**	0.97**	0.58*	0.65**

5% point for r - 11 d.f. 0.553; 50 d.f. = 0.273
1% point for r - 11 d.f. 0.684; 50 d.f. = 0.354
N.S. not significant.

APPENDIX XXXII

Correlation coefficients between Air Temperature and the respiration rate.

Correlation coefficients.

	DAYS	1	2	3	4	TOTALS
LARGEWHITES	1	0.89**	0.89**	0.83**	0.63*	0.86
	3	0.92**	0.87**	0.90**	0.59*	0.65
	7	0.83**	0.86**	0.80**	0.44 N.S.	0.60
BERKSHIRES	2	0.88**	0.85**	0.90**	0.65*	0.67
	4	0.90**	0.86**	0.89**	0.61*	0.65
	8	0.93**	0.92**	0.88**	0.62*	0.70

5% point for r = 11 d.f. 0.553;
1% point for r = 11 d.f. 0.684;
N.S. not significant.

APPENDIX XXXIII

Correlation coefficients between air temperature and the pulse rate.

	DAYS	1	2	3	4	TOTALS
		Correlation coefficients.				
LARGEWHITES	1	0.86**	0.99**	0.73**	0.42 N.S.	0.47**
	3	0.96**	0.96**	0.77**	0.92**	0.66**
	7	0.95**	0.90**	0.86**	0.40 N.S.	0.64**
BERKSHIRES	2	0.93**	0.88**	0.71**	0.72**	0.56**
	4	0.84**	0.87**	0.77**	0.80**	0.68**
	8	0.95**	0.92**	0.71**	0.59*	0.66**

N.S. = Non-significant

** = 1% point for r - 11 d.f. 0.584; 50 d.f. = 0.273

* 5% point for r - 11 d.f. 0.553; 50 d.f. = 0.354

APPENDIX XXXIV

Correlation coefficients between the air temperature and the skin temperature.

	DAYS	1	2	3	4	TOTALS
		Correlation coefficients.				
LARGEWHITES	1	0.95 **	0.92**	0.88**	0.98**	0.87
	3	0.93 **	0.91**	0.82*	0.92**	0.81
	7	0.93 **	0.92**	0.92**	0.92**	0.83
BERKSHIRES	2	0.96 **	0.93**	0.87**	0.93**	0.84
	4	0.97 **	0.93**	0.88**	0.98**	0.70
	8	0.99 **	0.90 **	0.90**	0.96**	0.79

* = 5% point for r - 5 d.f. 0.754; 26 d.f. 0.374

** 1% point for r - 5 d.f. 0.874; 26 d.f. 0.478

R A W   D A T A   F O R   I N D O O R   A N D

O U T D O O R   T R I A L.

APPENDIX XXXV

RECTAL TEMPERATURE ^{0}F.

INDOORS.

	Day	Large Whites 1	3	5	Berkshires 2	4	6
27.8.58	1	101.01	101.51	100.65	100.82	101.03	100.39
A.M.	2	100.08	100.14	100.64	100.08	100.16	101.16
	3	100.02	100.12	100.16	100.64	100.27	100.82
	4	100.39	100.76	100.26	100.25	100.72	100.36
	1	101.27	101.90	101.99	100.18	101.48	102.14
	2	101.35	101.87	101.76	101.16	101.48	101.97
	3	101.53	100.97	101.93	100.57	100.83	101.04
	4	101.01	101.65	100.26	101.05	100.84	100.15

OUTDOORS.

		7	9	11	8	10	12
	1	99.02	96.76	96.21	97.51	98.86	99.36
A.M.	2	98.64	96.42	96.30	99.66	99.50	98.08
	3	99.32	96.48	97.36	98.59	99.66	99.80
	4	97.54	96.33	96.18	98.88	98.32	98.36
	1	101.06	101.27	101.26	102.11	101.40	104.99
	2	102.81	102.12	102.36	102.96	101.82	104.99
	3	101.98	103.09	102.69	103.03	102.72	104.99
	4	103.38	103.52	103.86	103.20	103.70	104.98

Each reading is the mean of five measurements.
(For p.m. at hourly intervals between 1.15 - 3.15 and for p.m. at hourly intervals between 1.30 - 3.30).

APPENDIX XXXVI

Respiration Rate/Min.

A.M. Days.	INDOORS.						OUTDOORS.					
	LARGEWHITES			BERKSHIRES			LARGEWHITES			BERKSHIRES		
	Nos.1	3	5	2	4	6	7	9	11	8	10	12
1	11	10	11	11	12	11	10	11	11	11	12	12
2	11	10	11	10	11	11	10	10	10	10	11	10
3	11	11	11	11	11	12	11	11	11	10	10	12
4	10	12	10	10	10	10	10	10	10	11	10	11
1	32	24	26	23	23	25	74	56	58	63	57	87
2	27	26	26	28	29	29	99	111	110	98	99	139
3	27	26	34	23	24	22	97	95	106	66	72	100
4	20	24	24	25	26	27	94	105	111	87	68	147

EACH READING IS THE MEAN OF FIVE MEASUREMENTS.

APPENDIX XXXVII

PULSE BEATS/MIN.

		INDOORS						OUTDOORS					
		LARGEWHITES			BERKSHIRES			LARGEWHITES			BERKSHIRES		
	Days / Nos.	1	3	5	2	4	6	7	9	11	8	10	12
A.M.	1	71	74	72	70	69	72	70	72	72	69	71	72
	2	67	64	66	67	67	68	68	67	70	66	69	69
	3	68	68	67	70	66	69	68	69	68	70	72	77
	4	68	68	66	64	66	67	67	66	66	67	66	74
P.M.	1	83	83	84	82	84	84	104	100	116	103	107	112
	2	80	80	81	79	85	88	111	103	104	111	103	104
	3	84	79	83	77	79	79	99	106	106	110	110	121
	4	80	82	78	84	87	81	110	105	105	104	106	144

EACH READING IS THE MEAN OF FIVE MEASUREMENTS.

APPENDIX XXXVIII

Air Temperature °F.

		INDOORS.	OUTDOORS.
A.M.	1	64.0	49.6
	2	65.4	46.7
	3	64.0	51.0
	4	62.6	48.6
P.M.	1	64.80	55.80
	2	65.6	58.1
	3	65.4	57.7
	4	66.0	63.0

APPENDIX XXXIX

Rectal Remperature.

Analysis of Variance.

Source of Variation	S.S.	d.f.	M.S.	F	Result
Breeds	2.20	1	2.20	0.72	N.S.
Treatments	1.10	1	1.10	0.36	"
Times	48.19	1	48.19	1.92	"
Breeds x Treatments	3.05	1	3.05	0.43	"
Breeds x Times	0.45	1	0.45	0.00	"
Br. x Tr. x Times	0.08	1	0.08	0.00	"
Treatment x Times	25.12	1	25.12	3.51	"
Error	7.15	16	0.45	-	
TOTAL	87.34	23			

APPENDIX XXXX

Respiration Rate.

Source of Variation	S.S.	d.f.	M.S.	F	Result
Breeds	7.00	1	7.00	0.74	N.S.
Treatments	6501.00	1	6501.00	0.99	"
Times	13968.50	1	13968.50	2.13	"
Breeds x Tr.	3.10	1	3.10	0.00	"
Breeds x Times	9.50	1	9.50	0.01	"
Tr. x Times	6567.00	1	6567.00	87.16	**
Br. x Tr. x Ti.	1.60	1	1.60	0.00	N.S.
Error	1205.30	16	75.34	-	
TOTAL	28263.00	23			

All F values not significant unless otherwise shown.

** significant at 1% level.

APPENDIX XXXXI

Pulse Rate.

Source of Variation	S.S.	D.f.	M.S.	F	Result
Breeds	20.17	1	20.17	1.21	N.S.
Treatments	1148.17	1	1148.17	1.19	"
Times	4213.51	1	4213.51	4.38	"
Br. x Treat.	16.66	1	16.66	1.80	"
Br. x Times	10.66	1	10.66	1.15	"
Tr. x Times	962.66	1	962.66	104.05	**
Br.xTr.x Ti.	1.54	1	1.54	0.17	N.S.
Error	148.00	16	9.25	-	-
TOTAL	6521.37	23			

All F values not significant unless otherwise shown.

** significant at 1% level.