STUDIES OF VARIATION IN THE RECTAL TEMPERATURE, PULSE RATE, RESPIRATION RATE AND SKIN TEMPERATURE OF SOME NEW ZEALAND JERSEY COWS WITH PARTICULAR REFERENCE TO SUMMER CLIMATIC CONDITIONS

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by
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Animals are such agreeable friends - they ask no questions, they pass no criticisms.

George Eliot

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF APPENDICES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

The field of research known as Environmental Physiology covers studies on the physiological responses of animals to variations in their immediate environment and on the adaptation of animals to environment. Generally, studies with cattle in this field have been pursued either in tropical environments or, lately, in very cold climates (see series of papers by MacDonald and Bell, 1958). The use of climatic chambers, such as those described by Brody (1948) and by Findlay (1950), has enabled research workers to study the effects on animals of a wide range of climatic variables but the results have a restricted application in the field. The following broad questions have been posed:

1. With global transportation of livestock, is there a problem of adaptation to new environments and to what extent can such a problem be solved by the physiologist, geneticist and engineer?
2. To what extent is animal production affected, directly and indirectly, by extremes of climate?
3. How can animal breeders select animals that will thrive in a particular variable climate?
4. Is it necessary to shelter, or otherwise protect livestock against the direct effects of a particular climate?
5. What mechanisms are employed by an animal to regulate its own "private" climate?

Excellent reviews have been published on progress in seeking the answers to such questions, e.g. those of Findlay (1950), Findlay and Beakley (1954), Payne (1955) and McDowell (1958), to cite a few of the most comprehensive.

Scope of This Study

In general, studies in environmental physiology have not had any wide application in temperate countries such as New Zealand and no work has been done locally except for the pioneering study by Patchell (1951, 1954) and the studies by Hancock and Payne (1955) and Payne and Hancock (1957) which were made in Fiji and New Zealand. Apart from the fact that studies in this field are worthy, in their own right, of a place amongst physiological investigations, there are two major aspects of direct interest to New Zealand animal husbandmen.

The first concerns the possibility that the New Zealand climate may have a direct effect on the productivity of livestock and hence, that shelter and shade may be valuable. The second (touched upon in the twin papers of Hancock and Payne (1955) and Payne and Hancock (1957)) concerns the export of livestock from temperate to tropical environments. Many writers have stressed (Turbet, 1949; Payne and Hancock, 1957; Lecky, 1949) that some individuals among European-type cattle (Bos taurus) can thrive, and out-produce locally adapted cattle, in the tropics. As a general rule however, temperate-bred cattle fail upon exposure to tropical climates (Maule, 1952).

Four physiological variables (rectal temperature, pulse rate, respiration rate and skin temperature - indicators of the general physiological status of the animal) and one climatic variable (air temperature) were studied with the following types of question in mind:

1. What are the best ways of measuring, in the field, the variables concerned?

2. What variations are there in these variables (particularly diurnal and between animals) and what relationships exist among them?

3. What constitutes "normality" as regards the physiological variables and does the New Zealand summer climate cause any gross departures from normality (i.e. are the animals subjected to any direct climatic stress)?

4. What influences do various animal characteristics and managerial factors have on these physiological variables?

Also, is it possible to select on some physiological basis and in New Zealand, those animals that are likely to thrive if exported to a tropical country?

New Zealand Jersey cattle (B. taurus) were chosen for study since over 85% of the Dominion's dairy cow population is high-grade or purebred Jersey, (Primary Production in New Zealand, 1957).

Chapter I is introductory and explanatory in nature. Chapter II contains a review of the more recent literature pertinent to this study. Chapters III to VI inclusive describe experiments carried out in an attempt to answer some of the above questions while Chapter VII contains a summary of these experiments and the conclusions drawn therefrom.

Note on the Climatic Environment of the Manawatu

Kidson (1950) gives the three principal factors controlling the climate of New Zealand as:

1. Latitude.
2. Oceanic surroundings.
3. High relief.

New Zealand lies within the latitudes 34° 4'S and 47° 2'S and is therefore regarded as a temperate country. Within this latitude zone, westerly winds prevail and the country is subjected to rapid fluctuations in weather produced by a series of anti-cyclones and depressions moving continuously from west to east. The climate is predominately insular with an absence of extreme, short-term and seasonal variations in temperature. The high relief is responsible for important local modifications to the climate and the main mountain chain, which runs in a north east-south west direction, causes upward movements of air and, consequently, an irregular rainfall distribution.

The Manawatu district and the city of Palmerston North lie in "Middle New Zealand", the climate of which, states Garnier (1956), typifies that of New Zealand as a whole. Salient points of interest regarding the local climate are as follows:

1. The annual variations in mean monthly temperature is small (Climograph - figure 1). However, there is an extreme temperature range from above 80°F to below freezing point.
2. The mean diurnal range of temperature is surprisingly large due to a transparent atmosphere and clear skies. In Palmerston

North, the mean daily range is 15.3°F.

3. Low cloud can seldom form in extensive, continuous sheets.

4. The average precipitation is high (30 inches per year) and evenly spread but with some very intense rain over short periods.

5. In spite of the high rainfall and temperate climate, a high percentage of days have bright sunshine, due mainly to the periodicity of the rainfall and to the prevalence of wind. Palmerston North has, on average, 1,839 sunshine hours per year or 41% of the total possible hours.

6. A high proportion of the winds are strong.

7. Snow rarely occurs but frosts are quite common.

In general, because of the prevailing westerly winds and the central mountain chain, the western districts are wetter than the Eastern districts. This difference is most pronounced in spring when westerly winds prevail most persistently. Climatically and topographically, the western districts of the North Island (North Auckland, South Auckland, Taranaki and Wellington - including the Manawatu) are favourable for dairying and these four land districts between them pasture 85% of the National dairy herd (Farm Prodn. Statistics of New Zealand, 1958). Cattle in these dairying districts are subject, however, to raw westerly and south-westerly winds when no shelter is provided.

<u>Use of the Climograph</u>

The climograph is a method for comparing between climatic areas as to their suitability for a particular type of livestock (e.g. are two areas homoclimatic or heteroclimatic?). The origins of

CLIMOGRAPHS

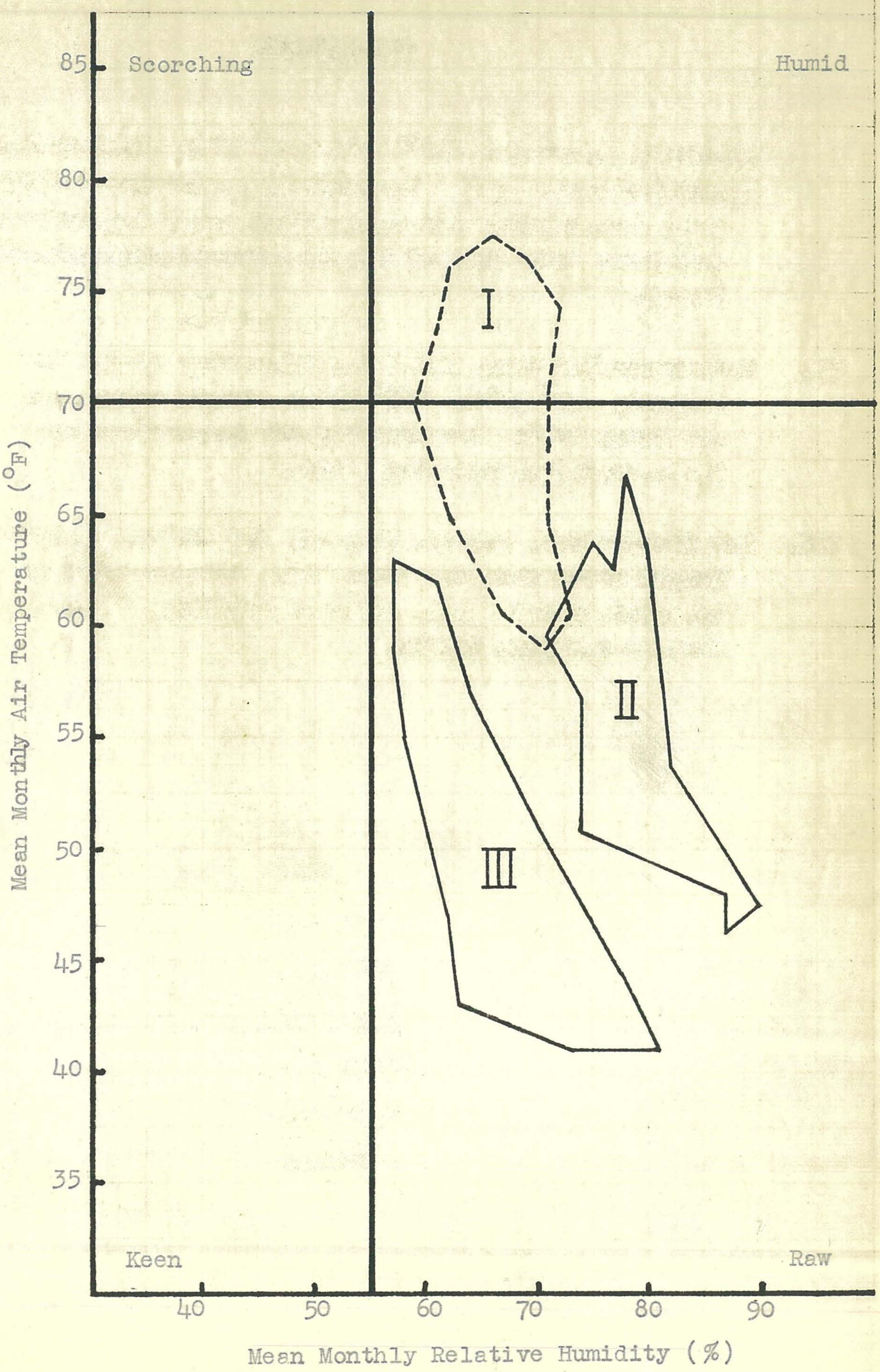
I. Brisbane, Australia; 27° 28' S, 153° 2' E; Height above mean sea level 134'; Standard 30 years' normal (1911-1940) mean monthly air temperature and 9 a.m. relative humidity; Year Book of the Commonwealth of Australia, (1957).

II. Grasslands Division, D.S.I.R., Palmerston North, New Zealand; 40° 23' S, 175° 37' E; Height above mean sea level 110'; Mean monthly air temperature and 9 a.m. relative humidity (1958).

III. Kew Observatory, Surrey, England; 51° 28' N, 0° 19' W; Height above mean sea level 18'; Mean monthly air temperature and 1 p.m. relative humidity; Your Weather Service, (1950).

FIGURE 1

CLIMOGRAPHS COMPARING THE MANAWATU WITH BRISBANE, AUSTRALIA AND SURREY, ENGLAND



the climograph have been given by Wright (1954). On a single graph are plotted the mean monthly air temperatures against the mean monthly relative humidities and the plots joined to form a figure, the position, shape and area of which reflects the summated environmental conditions. Figure 1 pictures climographs comparing the Manawatu with Brisbane (Australian tropics) and with South England (as an example of the climate from which New Zealand's cattle originally came).

Homeostasis and Normality

Homeothermic or "warm-blooded" animals, such as those of the Bos genus, require to maintain homeostasis in the face of fluctuating external climatic conditions. Homeostasis has been defined by Cannon (1929) as the maintenance of steady states in the body by means of complex, co-ordinated physiological reactions.

Hence, since cattle are homeothermic, their homeostatic mechanisms are utilised in the maintenance of a "normal" body temperature, the deep body temperature at which productive processes are most efficient. Measurements of rectal temperature, respiration rate, pulse rate, skin temperature and other, more or less, readily measureable variables have been made by physiologists and used as indicators of the physiological status of the animal. Any gross departures from "normality" have been interpreted as indicating some form of stress with implied adverse effects on production.

Many workers have used the term "normal" rather loosely in this context. In view of the large number of factors which have been shown to influence these variables, no one figure can be cited as normal for any cow in any normal situation when the cow is not under stress. Possibly, measurements taken when air temperatures are within the range for thermo-neutrality (40-60°F), as defined by Kibler and Brody (1949), should be regarded as normal. Beakley and Findlay (1955a) have suggested that measurements taken between 59°F and 68°F (15-20°C) air temperature are normal.

For rectal temperature, Dukes (1953) gives a range of 100.4-102.8°F as normal for a dairy cow, with a mean of 101.5°F. Wirth (1956) gives a range of 100.0 - 103.0°F for the ox and Brody (1945) gives a normal mean value of 101.0°F. From reports of work carried out on the mature Jersey cow within the approximate air temperature range of 40-80°F (Patchell, 1954a; Arrilaga et al, 1952; Badreldin et al, 1951; Riek and Lee, 1948a; Gaalaas, 1945; Regan and Richardson, 1938), the suggestion is made that Wirth's range could hold for the Jersey cow with possibly, an extension of the lower limit to 99.0°F. Any rectal temperatures falling outside the range of 99.0 - 103.0°F would then be considered abnormal. 101.1°F could be regarded as a mean value of rectal temperature but, as will be seen later, a mean value is of little significance in this work.

For pulse rate, Dukes (1953) gives a range of 60 - 70 beats/minute, Wirth (1956) 45-80 beats/minute and Findlay (1950) 60-70 beats/minute. Again, from a study of the same literature, Wirth's range could probably be accepted as normal for the mature Jersey cow with the reservation that rates above this range may not indicate thermal stress.

For respiration rate, Dukes (1955) gives a range of 18-28 respirations/minute and Wirth (1956) 10-30 respirations/minute as a normal range. In view of the gross changes seen in respiration rate at the higher air temperatures and the role of these changes in the maintenance of thermal equilibrium (Findlay and Beakley, 1954), elevated rates should, perhaps, not be considered abnormal unless they rise above rates measured at 70°F air temperature when these can be double the upper limit of Wirth (1956).

Patchell (1954a) gives a range of 80.0 - 100.1°F for the hip skin temperature of the Jersey two-year-old heifer and a mean of 93.8°F, within the air temperature range 36-68°F. Johnston et al (1958) found the mean skin temperature of three Jersey cows (five positions) to be 91.5°F, 95.1°F and 99.4°F at maximum air temperatures of 70°F, 85°F and 95°F respectively.

Heat Tolerance

The ability of an animal to withstand thermal stress (caused by the thermal elements of the climatic environment) determines the heat tolerance of the animal. Stress is defined as a condition of things compelling or characterised by a strained effort and it should be possible to see and measure such a strained effort. In attempting to discover the heat tolerance of cattle, workers have looked for evidence of a strained effort and associated effects on production.

Lee (1955) has pointed out that although strict, quantitative methods are demanded in animal breeding, an intuitive assessment might be more desirable in judging an animal's ability to control its internal homoeostatic environment in the face of climatic stress. Heat tolerance is a function of all the reactions of an animal body and thus, although quantitative information might be available, the final synthesis into some form of index will be largely intuitive.

Payne and Hancock (1957) have defined heat tolerance as the ability to maintain normal physiological function under heat stress. With adequate management (including nutrition and disease control) a normal animal in this sense should produce as well in a hot environment as in a temperate environment and the question naturally arises as to whether or not production *per se* is an adequate index of heat tolerance. Bonsma (1940) has pointed out that there is a tendency for species to develop to an optimum in a constant environment, leading to adaptation. An assessment of heat tolerance then, is an assessment of the ability of an animal to become adapted to a hot environment. The same author (1949) has stated that the reaction of any animal to a particular environmental stimulus is closely correlated with efficiency of production. An adapted animal should be an efficient producer (in terms of energy intake), with such factors as longevity and reproductive performance taken into consideration, as well as, in the case of dairy cattle, milk or butterfat production. A difficulty lies in measuring this productive efficiency. Perhaps the best that can be done at present is to measure production and measure heat tolerance, by the conventional means considered in the following section, and then to use some form of intuitive reasoning. Cattle do exist that combine both high production and heat tolerance (Maule, 1952).

Lee (1953) has listed the following factors as influencing heat tolerance:

Colour of coat and skin.

Depth and properties of coat.

Body form and surface area.

Wetness of coat and sweating ability.

Breed, age and sex.

In this study, colour, body form, age and productive performance have been considered with breed and sex constant.

The Measurement of Heat Tolerance

Lee (1953) has pointed out that some physiologists regard changes in rectal temperature as the sole criteria of heat tolerance, assuming that other physiological disturbances parallel disturbances to rectal temperature. Other workers have laid stress on production as the index of heat tolerance. Respiratory activity, fertility, coat character and blood composition have all been postulated as valid criteria in the assessment of heat tolerance in cattle and all have their proponents. Lee lists respiration rate, rectal temperature, surface temperature, yield, work capacity, reproductive activity, behaviour, growth and condition as animal reactions indicating the presence or absence of heat tolerance. Every physiological function of the animal must be considered when an attempt is being made to assess the ability of animals to thrive and produce under tropical conditions.

Rhoad (1944) pioneered the measurement of heat tolerance with his Iberia Heat Tolerance Coefficient, a field test under semi-standardised hot conditions and making use of changes in rectal temperature. The assumption is made that the normal rectal temperature is 101.0°F, but this is not necessarily true for every animal and later climatic chamber studies with account taken of the initial rectal temperature before exposure to heat (McDowell <u>et al</u>, 1955) are perhaps more valid. The field tests are not strictly comparable except to compare between animals within a set of readings. Respiration rate is utilised to separate animals which tie on the rectal temperature test and this idea has been further pursued by Benezra (1952) in his modification which takes respiration rate (assumed normal for cattle: 23 respirations/minute) into account. The assumption is that one animal, by reason of a lower respiration rate, may be equally well acclimatised as another with a lower rectal temperature. McDowell <u>et al</u> (1953a) have concluded in like manner, that increased respiratory activity is a compensatory response in the less tolerant animal.

De Alba and Sampaio (1957) have pointed out that short term climatic chamber tests are vitiated by nutritive conditions and the general adaptation of the animals to conditions outside the chamber. Environmental conditions during the intervals between tests seem to be important in the assessment of test results (Lee and Rick, 1951; McDowell <u>et al</u>, 1953b). Dowling (1956) has suggested that because of the high solar radiation heat load in parts of Australia, Rhoad's three-day exposure test simply becomes a measure of the time taken for the animal to lose control of temperature regulation rather than a measure of adaptive ability. This worker used exercise to raise the rectal temperatures of cattle for comparative purposes, taking care not to push the temperatures above 104°F. The results became available in a few hours and the tests were independent of weather conditions.

The effects of thermal stress may be seen in such physiological characteristics as the acid-base balance of the blood, blood composition and respiratory activity (other than rate). Rusoff et al (1951 and 1955) have studied the haemoglobin content, packed blood cell (haematocrit), plasma calcium and plasma inorganic phosphorous contents of the blood and Walker (1958) the haemoglobin index with the idea of utilising changes in blood composition as indices of heat tolerance. The results have been indefinite although the latter worker found an association between a high haemoglobin index and a high heat tolerance. Bianca (1955a) has studied the blood volume, plasma volume, blood cell volume and plasma total solids of calves in order to ascertain the effects of moisture loss during exposure to heat but could find few applications of this work to heat tolerance studies.

Findlay (1955) and McDowell et al (1953a) have suggested that the ability of an animal to decrease tidal volume with increasing respiration rate under hot conditions is a sign of heat tolerance since this results in less disturbance to normal alveolar ventilation and a reduced risk of inducing alkalosis of the blood by the "washing out" of carbon dioxide. Bianca (1955b), in a study of the acid-base balance of Ayrshire calves under thermal stress, concluded that increasing respiration rate causes a deficit in the blood carbon dioxide which is compensated for by a rise in the pH of the urine. This compensation is not affected by increases in lactic acid production by the respiratory muscles.

McDowell _et al_ (1953a) have suggested the use of respiratory volume as an index of heat tolerance rather than respiration rate because of a high positive correlation between the former and rectal temperature changes. However, rectal temperature is comparatively easy to measure and since it reflects the mean body temperature of the animal, it is a reasonable criterion of heat stress (Beakley and Findlay, 1955a).

Bonsma (1955) has stressed the use of coat characters and pigmentation as indicators of an animal's adaptability to a hot climate.