The Effect of Temperature on the Behavior
of the White Rat

by

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CHAPTER I

INTRODUCTION

For centuries people have been aware of a general relationship between climate and human behavior; however until a relatively recent date scientists have given little consideration to this problem. In more recent times physiologists, anthropologists, men of medicine, geographers, historians, and sociologists have made a serious attack on certain aspects of human ecology. The findings of these investigators should give impetus to research in many branches of science. But more than that, the investigations of such men as Wheeler, Huntington, Mills, Petersen, and many others have revealed astonishing data which demand an incorporation into the science of human behavior. It is a surprising fact to note that psychologists, as a group, have been slow in accepting the challenge given them in the form of data from the disciplines just mentioned--particularly physiology. The physiologist has much to say concerning the effect of various meteorological conditions on the organic processes of the body, and it remains for the psychologist to share the task of making the picture more complete.

A careful and serious consideration of the organism, as it preserves and maintains its form in an ever-changing environment, demonstrates the astonishing complexity of those processes concerned in the maintainance of equilibrium. The varying conditions of temperature, atmospheric pressure,

humidity, and a host of other environmental variants demand continuously from the organism an immediate and appropriate adjustment. Astonishing as the complexity of these more or less general adjustments may be, yet a more detailed scrutiny reveals further a large number of subsidiary equilibratory systems, which are concerned with maintaining certain biochemical and biophysical constants within the organism. Cannon (13) refers to these constants in his concept of homeostasis, and he treats of the processes concerned with acid-base relationships, temperature control, fluid content, along with many other intra-organic constants.

The physiologist who is aware of the complex interrelatedness of factors maintaining organic equilibrium in an environment continually in flux recognizes the danger in over-emphasizing the importance of one causal factor over others which may have an equally important function. The psychologist in resorting to physiological data for use in the explanation of psychological phenomena must recognize the importance of being doubly careful in not over-emphasizing one factor in the total system of causes. It behooves the psychologist to take this extra precaution for the reason that he is dealing with phenomena, some aspects of which cannot be described and explained entirely in terms of physiological concepts. The psychologist is confronted with a serious and important problem in deciding the extent to which, in psychological explanation, he should resort to physiological data

and theory.

The fundamental phenomenon of life is metabolism. The various chemical reactions concerned in the metabolic processes of all living tissue are certainly "fundamental" to any and all behavior manifested by the organism. Likewise, all environmental variations with which the metabolic processes must contend, and upon which they depend for their continuance, are equally "fundamental" to the organism's behavioral characteristics. Thus any climatic variation, such as temperature, atmospheric pressure, or humidity, is certainly not without effect on the metabolic status of the organism. The relationship between the behavioral characteristics of the organism and its metabolism is an important one; however it must be emphasized at this point that the dependence of behavior on body metabolism is not a dependence of such a nature that all the properties and characteristics of the former can be explained and described in terms of metabolic variations. If one makes such an attempt he falls into a logical fallacy. The proponents of the Gestalt School have repeatedly cautioned against this type of "reducibility". The psychologist and the physiologist are both dealing with descriptively different "material", all of which can be broken down through analysis to some form of energy or another. The fallacy in this type of procedure lies in the fact that in breaking down psychological and physiological phenomena into the same "thing" is to destroy the characteristic form or

quality of each. This form or quality has, in each case, definite properties which must enter into the description. A phenomenon may present itself in different levels of structuring, each level bearing properties which are determined and regulated by the dynamics of its particular organization. The danger in carrying analysis too far lies in the fact that it takes one beyond the level exhibiting the properties under question to a lower level where, of course, the properties are no longer existent. The phenomenal events in which the psychologist is interested require somewhat qualitatively different methods of explanation and analysis. There are, however, areas of overlapping with respect to the various sciences, and it is here where common concepts may be used most effectively.

The intent of the foregoing discussion has been (1) to emphasize the point that the psychologist, in research such as the present, must be especially cautious in not presupposing a one to one causal relationship between isolated physical happenings and concomitant psychological phenomena.

(2) It has been pointed out that in psychology as well as physiology the "cause" must be looked for in terms of a configuration of causes. (3) Care must be taken not to overemphasize one factor in the total causal configuration at the expense of others.

In considering the effect of climate on behavior, these cautions must be carefully considered. That aspect of the

environment which is the climate imposes conditions on the organism which are infinitely complex and which are continuously changing. In maintaining constant equilibrium under these conditions the organism displays remarkable adeptness. So complex is the response to atmospheric changes that it is very difficult in many instances to differentiate cause and effect relationships even in a general way.

It is generally recognized that there are many approaches to the study of human behavior. Each particular approach has been emphasized by those who consider it to be the most fruitful. Present day psychology demonstrates these approaches by an emphasis, on the one hand, on the individual, and on the other, on the group. Still another approach is through the study of animal behavior with the hope of subsequently throwing light on human behavior. This list of approaches to the problem can be increased to a much larger size; however, regardless of the particular approach to be emphasized, the investigator must recognize that through this approach alone, he arrives at only one aspect of the complete picture.

The universe seems definitely not to be merely an aggregate of separate bits and parts, thrown together by chance--each part functioning and displaying properties in and of its own right. On the contrary, the most immediate and most universal characteristic of the universe is that of order, system and patterning. The universe is a unitary system displaying organization and inter-connectedness in a hierarchy of patterned

structure. From this point of view, the organism cannot be a static entity existing alone, by itself, and independent of the rhythm and inter-action which characterizes the rest of the universe. The organism is a participating structure, functioning along with as well as because of an environment. The organism and its environment are a complete unit, and this unit should be the starting point of all biological science.

In the case of certain organisms such as the human being, for example, a high level of patterning is displayed. There are many characteristics with respect to social structure which remain for observation and study only when the group approach is maintained. The use of a rigid analytical method reduces the group, as such, to a sterile abstraction and brings about the destruction of the very characteristics in question. This point is made with reference to biological characteristics as well as social characteristics. Many of the effects of climate on human behavior manifest themselves only when the observation is made on intact regional units. There are certainly biological properties which do not exist apart from groups--properties of form of one kind or another. The work of Allee (3) is especially significant in this respect. It might be found that a certain climatic variation leaves no observable alteration in the function or behavior of an individual organism, yet it is possible that this very same climatic variation may leave effects observable in the group as a whole. As an example of this we might refer to the seasonal occurrence of

certain common diseases. These biological characteristics can be observed only by making observations on groups. The characteristics are absent with respect to a single individual. These points are emphasized because the scientist can easily miss many aspects of the picture when he fails to make observations at every level and from every angle.

Before a thorough understanding of human behavior can be attained, a broad extended view must be incorporated into the study of the problem along with an intensive and detailed analysis. There is a definite need in psychology for research which can forget for the time being the multitude of particularized forms of behavior and proceed to study the individual as he responds to more or less general variations in the environment. There is need also of going further and studying the group behavior which occurs with these general environmental changes. Bews (10), in discussing human ecology, speaks of the fundamental biological triad--environment, function, and organism. He points out that this triad must be studied as one complete unit. This, according to Bews, is human ecology. There is need for studies in psychology which utilize the ecological approach. Until the results of such an approach are incorporated into the theory of human behavior, psychology will be sadly lacking in breadth of vision, completeness of understanding, and ability to control and predict with regard to psychological phenomena.

It is well to point out here that ecological data are

certainly not unavailable to psychology at the present time. A cursory examination of the literature reveals an astonishingly large amount of information which demands a place in the science of human behavior. Information pertinent to the science of psychology is available not only from the realm of ecology proper, but also from other fields as well--particularly medical climatology.

Various persons have suggested climate as an important factor in determining the behavioral characteristics of a people. At a very early date in the history of science this relationship was suggested by none other than Hippocrates in his text on "Airs, Waters, Places". Casual observations as to the physical and psychological characteristics and productivity of people living in different climatic regions suggest a definite relationship. A more detailed examination of peoples living in different regions of the earth demonstrates vast differences in their respective contributions to the arts, sciences, literature, and religion. Among other things, these different regions are characterized by vastly different climates; this fact suggests a causal relationship. Referring to common every day observation, one notes that continual references are made to the effect on behavior of daily weather changes, along with the seasonal variations. The effects are so commonplace that their mention is made in the literature of peoples. Poets and writers all over the world have referred again and again to the influence of weather and climate on the feelings,

attitudes, and behavior of people. "In the spring a young man's fancy lightly turns to thoughts of love" is one example of many such references.

It is commonly accepted that people living in warm climates are more or less listless, quick-tempered, and passionate, while those living in the cooler regions of the earth are more active and consequently more productive, more even-tempered, with more control over their passions. It is also commonly accepted that the peoples of the cooler climates (but not exceptionally cold) are more progressive, exhibit stronger leadership, and maintain a higher level of efficiency with respect to all the problems of living than do the people who inhabit the warmer regions of the earth.

Common every day experiences and observations such as the above have served to prompt a real scientific curiosity and inquiry as to the causal relationship between climate and the general characteristics of peoples, behavioral and otherwise. There is yet, however, much speculation and theory as to the exact nature and extent of the effect of climate with its numerous variables on human behavior. There is need for exacting psychological studies in order to verify many of the generalizations made by the pioneers in this field. This, then, in the purpose of the present program of research, the results of which follow in the subsequent chapters.

CHAPTER II

SURVEY OF THE LITERATURE

In the foregoing discussion, the necessity of the holistic point of view in science, was stressed. The infinite complexity of the organic processes which are manifested by the organism in its constant and continuous adjustments to the environment was emphasized. Necessary cautions were pointed out with respect to an unwarranted over-emphasis on one variable in a whole configuration of variables in a statement of cause and effect relationships. The danger in an insistence on a rigid structural analysis was also pointed out. These considerations were discussed with special reference to studies such as the present one, the purpose, method, and results of which follow in subsequent chapters.

Much has been written concerning general observations made with respect to the influence of climate in determining the character and productiveness of a people. Many observers have noted such a relationship in considering the relative contributions of people who live in hot or cold climates to art, literature, and the sciences. Races living in regions of climatic extremes exhibit striking psychological as well as physical differences. Novakovsky (70) uses the expression "arctic hysteria" in his description of the mechanical, imitative behavior found in arctic peoples during the winter. On the other hand, everyone is aware of the listless, sluggish, inattentive, and lazy characteristics of peoples living in the

heat of the tropics. It is generally recognized that human productivity is greatest in regions of climatic optimum, and that either climatic extreme makes for a lessening in human productivity. Huntington (34) points out that regional location of the great civilizations of history cannot be explained in terms of chance. Hellpach (22) observed that Anglo Saxons going to Brazil soon become "easy going and sluggish". Moss (69) suggests that numerous factors, such as climate, altitude, temperature, humidity, time of day, and ventilation, affect the metabolic status of the organism. McFarland (45) has made detailed observations of the effect of oxygen deprivation on the behavior of individuals. He believes anoxemia to affect behavior through its effect on the metabolic status of the organism. It has been supposed by many that hot climates lower the metabolic rate of its inhabitants. This is shown by MacLeod, Crofts and Benedict (40), who report the metabolic rate of the Chinese and Japanese to be on the average 10% below the level usually considered normal.

The effect of temperature on the emotional life of individuals is known to be significant. The inhabitants of warm countries are characteristically more quick-tempered and passionate as indicated by the relative number of crimes. Murders are more numerous in the warm climates of Spain and Italy and are less frequent in the cooler countries of England, Scotland, and Holland. Ishii (36) reports that in Japan the maximum number of murders and crimes involving bodily injury come

during August, and that there is a rapid decline during the winter months. Huntington (34) and Dexter (16) find that there is a seasonal fluctuation with respect to the amount and efficiency of both mental and physical work. Many other general observations such as these have been made; however it is not our purpose here to consider this literature in detail. The subsequent portions of this chapter are concerned with studies which are more specifically pertinent to the present study.

A study of far-reaching and astonishing implications has been made by R. H. Wheeler (90-93) on the effect of climate on human behavior. The results of this extensive study will fill volumes, three of which have already been written. These three volumes are to be published in the near future. Elsworth Huntington, in an introduction written for Wheeler's first volume, makes the following statement concerning the import of this work, "This book seems to me to be one of the few that are destined to be a potent influence in future generations".

Space does not permit a detailed review of the entire study; however, since this project has, in the main, served to prompt the present investigation, a careful survey will be made in an attempt to present a statement of the basic postulates along with an exposition of some of the chief findings and conclusions.

The study began as a problem in the history of psychology. More specifically, it had its beginning in an historical

consideration of systematic positions in psychology. Wheeler observed, for example, that in the history of psychology, opposing points of view developed from basic postulates which held a contradictory relationship to each other. Thus as Wheeler puts it, "the two modes of approach were both methodologically and logically opposite". In recent decades these two modes of approach are exemplified in Behaviorism and Conditioned Response Psychology on the one hand, and in Gestalt or Organismic Psychology on the other. Upon further observations, Wheeler found that these same opposing patterns were found in the history of biology and philosophy and that they all alternated synchronously throughout history. Furthermore, after more careful consideration was given to the problem in the form of research, it was found that the entire culture pattern fluctuated not only in such a way that it included all the arts and sciences, but also in such a way that it was in rhythm with the rise and fall of governments and general shifts in attitude, feeling, purpose and judgment of the people within the culture pattern. Only after a curve of these fluctuating cycles was plotted, was it suspected that they might bear a relation to a correspondingly rhythmic environmental fluctuation in climate. Upon examining the California Sequoia curve in relation to these culture cycles, Wheeler found a correspondence "in a manner which could not be accounted for by chance". This critical observation led to the extensive program of research which is resulting in

much information concerning the effect of climate on all aspects of human behavior.

Wheeler has gone beyond the level of description in this study and has differentiated it at an explanatory level. In this connection he has set forth a basic postulate to the effect that human behavior is a function of a total energy field. The following discussion will be concerned with a brief examination of the basic postulates made by Wheeler with respect to the relationship between human behavior and climate.

In connection with the possibility of a world climate, Wheeler (93) points out that the various climatic cycles over large continental areas are synchronized to the extent that one is justified in using the expression "world climate". Furthermore, he explains that these climatic cycles generally appear in the form of shifts from warm to cold, the first half of each being wet, the second half dry. This of course means that droughts are of two kinds, hot and cold, and that wet periods shift from warm to cold. Quoting (93),

"The usual cycle passes through the following stages: (a) a cold-dry maximum; (b) recovery of temperature ahead of rainfall, hence a short, warm termination of a cold, drought era; (c) a striking warm-wet maximum (which if long enough, has a strong cold-wet break or 'saddle') turning to (d) hot and dry. Then on a falling temperature curve, rainfall undergoes a secondary recovery, resulting in fairly marked cold-wet phase as a warm epoch shifts to cold. Then it becomes dry again, and the cycle is repeated." (p. 231)

In a recent article, Wheeler (93) elaborates on his basic assumption that man's behavior is a function of the total field of energy and in this elaboration summarizes the

nature of the relationship between climatic shifts and human behavior. He says,

"A culture pattern, or behavior pattern of human beings in social groups, has consistently shifted from an emphasis on one set of variables to its opposite along with shifts from cold-dry to warm-wet maxima". (p. 232)

The number of these variables which he has studied is large and only a short list would include such fields as: politics; economics; social, religious, and educational phenomena and procedures; literature; art; music; fashion; science and philosophy; psychology; social science; inventions. In order to give a more detailed account of these variables as they fluctuate along with the climatic shifts, we again quote from Wheeler (93),

"The mentality of classical, warm periods is much more profound than that of cold periods, as measured by philosophy, science, art, and literature. These are periods when culture is dominated by a wealthy aristocracy. Cold periods are dominated by a democratically minded middle class of more humble, but of no less important achievements. Warm periods are organic; cold periods, atomistic. The warm are idealistic, the cold, utilitarian; the former, rational, the latter, empirical; the former, 'time minded', the latter, 'space minded'". (p. 232)

Wheeler believes that some energy principle is needed to explain the psychological differences between these two patterns of behavior, for he finds that as the activity of the environment increases, a corresponding increase in man's activity also manifests itself in the arts, sciences, literature, and wars. Likewise, as environmental activity decreases, man's activity decreases. This is illustrated especially well in

his study by the fact that man's best and greatest achievements have been made during transition periods--from cold to warm and back again. This is demonstrated mainly by the clustering of wars, migrations, explorations, revolts, etc., at these transition times. The energy principle thus involved is compared to the principle of the pendulum, with the point of maximum energy at the mid-point of the pendulum's swing from one extreme of the arc to the other. As the point of minimum energy occurs at the end of the arc where the pendulum stops for an instant and reverses its direction, so the periods of maximum and minimum temperatures in the climatic swing are the quietest.

In order to obtain a more differentiated picture of the psychological characteristics which Wheeler finds exhibited by the people within a culture during corresponding cold and warm times, a brief examination will be made concerning the integrated human culture pattern in existence during each respective time. In government we find centralization, monarchism, dictatorships, rising national spirit, world wars, tyranny, and delimitation of franchise on the warm side; on the cold side appear de-centralization, rise of the masses, republicanism, falling national spirit, civil wars, broadening of the franchise, and restoration of democracy. Warm times ultimately bring socialism and communism while individualism appears with cold times. The rise of an aristocracy introduces the former; the rise of a new proletariat,

the latter. Monotheism and rational theology come on the warm side and polytheism with a theology of faith on the cold. Evidence shows an increase in abnormal sex behavior during warm times with a decrease in such practices as it becomes cooler.

With respect to literature, the warm side brings the classical, philosophical, heavy tragedy, disciplined love, heavy drama, and abstract themes; the cold side brings the descriptive, the romantic-light comedy, light drama, vulgar comedy, free love, simple rhyme and rhythm. Art behaves in much the same manner as literature, with the classical and abstract appearing in warm times and the romantic and concrete following in cold times. In matters of dress, warm times bring the simple, plain, and dignified; whereas during cold times, the complex, ornate, and elaborate appear.

In the most differentiated realms of human endeavor, namely, science and philosophy, warm times seem to bring emphasis on deduction, primacy of the whole, relativity concepts, universal laws, unity of science, discussion on the explanatory level, teleology, monism, breakdown of dualisms, and vitalism; whereas we find ushered in on the cold side an emphasis on induction, primacy of the part, innate properties and attributes, specialized laws, discreteness of the sciences, atomism, mechanistic assumptions, discussion at a descriptive level, empirical laws, nature regarded as fortuitous, dualisms, and dichotomies. In philosophy the former brings monism,

idealism (epistemology), and emergent evolution; the latter is associated with pluralism, empiricism, and creation by fiat.

With reference to psychology in particular, rationalism, formalism, gestalt, introspectionism, and an emphasis on learning through discovery come with warm times; appearing with cold times are empiricism, behaviorism, associationism, and learning by drill.

Kenneth Moore (68), in working on a particular branch of this whole project, compared the data on climatic fluctuations from 600 B. C., to 1300 A. D. with the works of scientists as listed in Sarton's three volume work. He classified these scientists into two groups according to Wheeler's organismic (warm) and mechanistic (cold) behavior variables. All of his coefficients of correlation, were positive, ranging from $+0.33$ to $+0.63$. He concludes that these coefficients are significant to the extent of warranting the thesis that there is a relationship between the existing climatic pattern and the prevailing pattern of scientific thought.

Ellsworth Huntington (34) has studied the effect of climate on civilization and has related the rise and fall of nations to pulsatory climatic changes. Although primarily a geographer, Huntington emphasizes the physiological approach and cites much data with respect to the effect of climate on human behavior. He believes tropical climates are conducive to laziness, drunkenness, immorality, and lack

of will power. In this connection he has compared people of the same type who have settled in regions of different climatic characteristics. He reports that the descendants of those who settled, for example, in Ontario, Canada, were energetic and progressive, while those who were descendants of settlers in the Bahamas were lazy, inefficient, unprogressive, and incompetent. In cooler regions, as well as in the warmer ones, he finds seasonal variations in the levels of both mental and physical work. For example, scholastic grades of West Point Cadets vary with the season of the year, as does the percentage of those passing Civil Service Examinations. Huntington concludes that effects such as these suggest an optimum temperature range for both physical and mental work. He sets 38° F for the mental optimum and 60°-70° F for the physical optimum.

In a recent book, Season of Birth (33), Huntington considers that a basic animal rhythm proceeding in harmony with seasonal climatic fluctuations, is responsible for the fact that a greater number of births occur during one season than during another. He believes this to be due to a definite seasonal rhythm of reproduction which is universal and similar to that which is exhibited by all other higher animals. Furthermore, he suggests that man has acquired this rhythmic pattern because it favored the survival of the young.

Huntington believes that the seasonal distribution of births depends to a great extent upon the weather. In this

connection he considers temperature the most important factor and he points out that the maximum number of conceptions is reached during the time when the temperature averages around 62° F. This, then, he suggests, is the optimum temperature for conception. In the temperate regions of the earth this optimum is reached in the spring during the months of April, May, and June. The births resulting from conceptions during these months occur in January, February, and March. Huntington finds more births occurring during these latter months and points out that persons of eminence tend to be born at this time. According to Huntington, people who are born in March, in New England, live an average of four years longer than those born in July. He finds also that defective or handicapped people tend to be conceived during the time of the peak in the reproductive rhythm; however there is also a tendency for mentally and physically defective children to be conceived during the high temperatures of the summer months. Summarizing his studies (33), Huntington says,

"This brings us back to our main conclusion that the basic animal rhythm of reproduction permeates our lives in many ways that have been little suspected. The season at which people are born affects the number of births, the percentage of boys compared with girls, the rate of infant mortality, the duration of life after the dangers of infancy are passed. It also affects the percentage of criminals, tubercular patients, and persons who suffer from insanity. Later in life the onset of the active phase of the annual reproductive cycle creates a kind of excitement which manifests itself in sexual crimes, insanity, and suicide, and probably in many other ways. The season at which people are conceived, and the temperature of the region where they are conceived, also have a good deal to do with

the number who rise to the heights of fame. And finally an inherited adaptation causes us to react to the weather in different ways according to our age from infancy onward. When the indirect effects of such conditions are considered there seems to be scarcely a person or a phase of life which is not vitally influenced by the season at which people are born and the season at which the reproductive urge becomes strongest." (p. 424)

Huntington (31) believes also that atmospheric ozone is definitely related to mental functions. He reports a study by Dobson and others which shows that atmospheric ozone reaches a maximum in late winter and early spring. He reports also the work of Tchijewski, who found that rats were more active, both physically and sexually, when subjected to ionized air for several hours. According to Huntington, Tchijewski observed that animals living in this kind of air recuperated more quickly from an inoculation of tuberculosis than did other animals. Huntington suggests that mental activity is definitely related to the amount of atmospheric ozone.

In the realm of medical climatology, a formidable attack has been made on the problem. In spite of the fact that this discipline is young and has so far attracted the interests of relatively few scientists, massive amounts of data have been collected which correlate body function and dysfunction with meteorological variations. Especially pertinent here is the work of Petersen (76) and Mills (47-67).

Petersen's findings are reported in a three volume work entitled, "The Patient and the Weather" (76). The first

volume is concerned with a survey and interpretation of disease as it is affected and conditioned by meteorological factors in "bringing about stimulation, overstimulation, fatigue and death". Here he considers also the regional distribution of disease and discusses in a detailed fashion the meteorological effect on organ function and dysfunction. He points out that even in the normal individual there is a constant reaction to the meteorological environment in the form of a chemical and endocrine rhythm. The second volume is given over to a consideration of clinical cases unusually responsive to meteorological variations. In the third volume, detailed studies are reported of the relation between meteorological events and nervous and mental diseases.

Petersen looks on the organism as a "Cosmic Resonator". In this connection he emphasizes the integrative action of the autonomic system as the mediator and sounding board of "cosmic" pulsations. In his consideration of the autonomic system he speaks of the "Autonomic Trinity", referring to the integrated nature of the chemical, endocrine, and nervous aspects of the system. Elaborating as to the meaning and implications of this concept, he goes on to explain that there can be no disturbance in the chemical balance without the occurrence of tissue alterations in relation to autonomic nerve impulses and the hormones. Neither can there be any change in the hormone balance without a different reaction of the tissues to chemical and neural effects. Likewise

a disturbance in the nerve balance of the tissues results in an alteration of the reaction to hormone and chemical control. Petersen suggests that the autonomic system is particularly responsive to changes in the atmospheric environment.

In considering the metabolic system, Petersen differentiates two relatively distinct phases. He labels the one ARS and the other COD. In his own words (76),

"The abbreviations ARS and COD are used to designate functional poles. A. (Anabolism-alkalinity) R. (Preponderance of reduction), S. (Spasm) i.e., that status when the systolic blood pressure is increasing. It is presumably associated with adrenal preponderance In the tissues of the region supplied by the spastic vessels the tissues are becoming more and more anoxic, are being stimulated, CO₂ is being accumulated."

"This phase goes over gradually or abruptly to the corrective or opposite pole COD, i.e., C (Catabolism), O (Oxidation), D (Dilation of the vessels) with falling diastolic blood pressure and presumably a thyroid preponderance. During this time the tissues are of course changing from the period of a maximum acidosis toward the alkaline side, the metabolic rate of the cells is diminishing, CO₂ diminishes etc." (p. 9, Vol. 3).

Petersen points out that any system of the body must be capable of making immediate adjustment to any change in the humoral milieu if normal organic sequences are to continue. However, if such is not the case, that is, if a system fails to adjust to these alterations and proceeds in an individual fashion more or less outside the control of the organic whole, then this organic expression is termed a "focal reaction". The focal reaction represents an inadequacy on the part of

the metabolic system to adjust to the environmental changes. The obviousness of a focal reaction depends on the area involved. Thus the involvement of certain tissues may result in no clinically observable dysfunction; but when others are affected, a well-defined clinical picture may present itself. Petersen considers such to be the case when under great provocation an otherwise normal nervous mechanism suddenly becomes inadequate.

Petersen believes the characteristic behavior of the pyknic and the leptosome types present, in each case, a general metabolic picture which is conditioned by environmental factors. He emphasizes fluctuations in the meteorological environment as being of primary importance. For example, he points out that the leptosome type (poorly buffered) becomes morose and then irritable during the COD phase, under rising temperatures. This phase is represented by cellular irritability, increased cellular permeability, lowered blood pressure, and acidosis; whereas the pyknic type is unaffected by this phase, and feels energetic and well during the ARS phase, under falling temperatures.

He considers the primary characteristic of the schizophrenic as being that of an inherent "somatic irritability". The schizophrenic is "chemically associated" with the COD phase in the metabolic cycle; thus the leptosome type can be expected to manifest schizophrenic characteristics when environmental conditions are such as to favor the COD phase.

Characterizing the schizophrenic, Petersen says (76),

"This means an individual who is less well buffered, whose metabolic and chemical swings are of greater amplitude, who is more acid, whose tissues are stimulated to a greater degree, whose vascular bed is dilated (particularly arterioles and capillaries) but who, because of the limited blood mass at his disposal, must husband the supply and does so by shunting the blood mass rapidly from one region to another. Such an individual, who has calcium that is well ionized and not readily deposited, whose reserves are few, and who oxidizes at a high rate, is preponderantly a "thyroid" rather than an "adrenal" type." (p. 300, Vol. 3)

Speaking of the manic depressive, he says,

"In a typical manic depressive patient we have an individual in whom the chemical cycles are damped because more adequately buffered; with a lowered rate of oxidation (or at least an adequacy of oxygenation so that periods of anoxemic stimulation are less pronounced and less frequent); with a greater tendency toward alkalosis rather than acidosis, with lessened permeability of cells and a generally lower rate of metabolic activity and consequently molecular motion. Such an individual must accumulate reserves and will thereby become more stable; and being more alkaline develops a heavier bony framework." (p. 297, Vol. 3)

Much of Petersen's study is concerned with regional distribution of diseases. He reports wide differences (especially those of metabolic dysfunction) existing in regions with correspondingly different climatic conditions. He also reports a marked regional and seasonal distribution in malformations, intelligence, and conception rate.

Petersen made a series of daily observations over a long period of time on four subjects. Here he made the usual clinical observations, such as blood pressure, temperature, and leucocyte count, as well as detailed checks on the biochemical blood changes. In this connection it was found that

the "normal fluctuations of blood chemical levels" follow a definite rhythmic pattern. Petersen points out that these chemical rhythms are conditioned largely by meteorological conditions. Definitely correlated with meteorological variations are such biochemical factors as: general metabolic rate; leucocyte count; oxidation-reduction; body temperature; blood pressure and pulse rate; non-protein nitrogen, sugar, cholesterol, chlorides, and phosphates; CO₂ content, blood pH, calcium, potassium, protein, permeability, and blister time. The chemistry of the urine shows also a meteorological correlation. He further points out that such dysfunctions as headache, colds and gastro-intestinal disturbances likewise reflect the meteorological environment. Going further, Petersen insists that the moods of his subjects and various other psychological manifestations are associated with meteorological alterations.

Space does not permit a detailed consideration of the manner in which Petersen finds each of the above affected by changes in the meteorological environment. Referring to this very tedious and detailed clinical data Petersen says (76),

" . . . all the conclusions drawn and all the inferences suggested, are demonstrable by the simplest of clinical methods. Any one who can count the pulse rate or take a blood pressure or who can titrate the urine, can follow the changing tide of the organism as it swings with the meteorological status."
(p. 160, Vol. 1, Part 2)

In detailed case studies of psychotics and neurotics,

Petersen has been able to show a relationship between the meteorological status and the various psychotic and neurotic episodes exhibited by the patient. These case studies are reported in Volume Three.

Mills (47-67), also working in the field of medical climatology, attacks the problem in a similar fashion. The differences in productivity, reactions to diseases, and general body build as found in human beings living in various regions of the earth, he attributes to differences in availability of usable energy. Fundamental to Mills' study is the idea of the energy basis of existence. He points out that man's vitality and productiveness vary from region to region. He believes that an important factor in the general existence level of man and animals is the ease or difficulty with which the organism rids itself of body heat, for as heat loss becomes difficult, all body functions are lessened, and this results in a general decrease in activity. On the other hand, as heat loss becomes easier, all body functions are increased, thus the general level of activity is increased. Mills reports studies which show a direct relationship in both man and animals between immediate external temperature level and internal combustion rate. In studying this problem, Mills himself has done extensive research with animals.

Statistics cited by Mills show clearly what he calls climatic dominance over growth. He reports that children born and raised in the tropics are smaller at birth, develop

more slowly, and are smaller in adulthood than those reared in more stimulating climatic conditions. He points out also that puberty comes on later in the tropics and that sexual maturity is reached later. Further he says (47),

"Nowhere on earth do children develop so lustily, nor reach puberty so early, as in the upper half of the Mississippi river basin where the climatic drive is so intense. Both children and adults show there a more robust figure--more pounds of weight per inch of height --than do those growing up in tropical warmth."
(p. 27)

Mills reports measurements which show an increase in the average height and weight of college students as one goes from the southern portions to the northern sections of the United States.

Since fertility and sexual functions are closely related to the general combustion level of the individual, through pituitary and adrenal control, these functions are also affected by climatic stimulation and depression. In this connection, Mills has shown wide seasonal variation in the conception rate. In general, in the north temperate zone, the peak in number of conceptions is reached in the spring --April, May, and June, and declines as the temperature continues to rise in the summer. Of course, this depends somewhat on the locality. Figure I, taken from Mills, shows this seasonal variation for Wichita, Kansas; figure II demonstrates this variation for Japan.

Mills points out that the most outstanding seasonal change in fertility is found in Japan. Figure II shows a very

FIGURE II

GRAPH OF SEASONAL VARIATIONS IN
CONCEPTIONS(JAPAN) (AFTER MILLS)

FIGURE I

GRAPH OF SEASONAL VARIATIONS IN
CONCEPTIONS(WICHITA)(AFTER MILLS)

rapid decline in fertility as moist heat appears with the summer months of July, August, and September. Fertility runs high from mid-March to June. Mills insists that the decline in fertility as represented by a falling off in conception rate is a real lessening in fertility rather than a decrease in number of matings. He substantiates this by citing monthly data from the houses of prostitution which show no particular variation throughout the year. Mills reports studies by Belding, who examined the number of active spermatozoa in human semen during the various seasons of the year. He showed that the number reached a peak in June and declined during the summer months. Another peak occurred in late September. These observations were made in Boston, Mass.

Mills, like Petersen, places much emphasis on the general

meteorological instability as a disturbing factor in physiological functions. He considers the intensity of the climatic drive in terms of "storm stress or atmospheric turbulence" as being important in determining man's general energy level as well as in determining the rapidity with which there is bodily breakdown from metabolic diseases; thus Mills shows that metabolic diseases, such as diabetes, goiter, pernicious anemia, and leukemia, are regionally distributed and are more severe where the climatic stress is greatest. He shows also that climatic conditions are factors in infectious diseases such as leprosy, appendicitis, nephritis, and tuberculosis. In this connection, Mills points out that people living in regions of moist heat exhibit low levels of energy and bodily function and are consequently unable to resist infections. Sclerosis and failure in the vascular system bear a relationship to regional climatic characteristics as well as to seasonal fluctuations. Mills reports that sclerosis is "predominantly a temperate zone problem". He goes on to say (47),

"Teaching centers in moist heat regions have difficulty finding enough well defined sclerotic case material for demonstration purposes, while in middle temperate regions sclerotic cases comprise probably the largest single medical disease group for hospitalization." (p. 165)

Mills points out that the rate of oxidation in the gray matter of the brain is many times higher than in any other tissue of the body; thus one is led to expect the incidence

of mental breakdown to be higher in those regions where the climatic stress is greatest; however he reports that statistics are not available to verify this expectation. As a general index of mental instability and breakdown, Mills shows how the incidence of suicides and homicides is regionally distributed. He finds that both homicide and suicide, in terms of frequency, follow the general paths of storms across the country. The incidence of suicide is higher during times of approaching storm-fronts. In regard to the effect of storms on mental function Mills says (47),

"With a center of low pressure approaching--the pressure falling and the temperature rising--we are afflicted with a feeling of futility, an inability to reach the usual mental efficiency, or to accomplish difficult tasks. In children this takes the form of an increased irritability, a restlessness and petulance that parents find most trying. Adults on such days are also more quarrelsome and fault finding, with a tendency to a pessimistic viewpoint toward all matters that arise. Such weather provides the most perfect background for marital outburst of temper."

"These periods rapidly shift, as the storm front passes, into the phase of falling temperature and rising pressure, with clear, cool, exhilarating weather for a few days. It is on these days that we are buoyed up and find our difficulties fading away. Tasks are more easily accomplished and mental efficiency is at a high level. Musicians and artists are indeed fortunate if they have such weather for their peaks of performance." (p. 177)

Mills (47) reports a definite seasonal pattern in regard to the hospitalization of mental cases. According to him the number of admissions reached a peak in the late winter and spring and falls steadily through the summer and fall months when the climatic conditions are less stimulating. He reports

also that the incidence of rheumatic fever attacks and rheumatic heart disease in the worst areas of the storm zone is ten to twenty times that in the tropics. It is also to be pointed out that there is a significant seasonal variation in this incidence as shown in a winter high and a summer low in the areas of greatest climatic stress.

Much literature has accumulated which concerns the physiological reactions of the organism to temperature changes, yet the subject is very complicated and little understood. A detailed review of all the literature dealing with this problem is not pertinent to the present study. However there are a number of facts which should be carefully considered at this point.

Homiothermic animals must adapt to two sources of heat: that from the inside which is a product of metabolism, and that from without. In general the heat regulatory mechanism of the body concerns itself with two functions, namely, conservation and dissipation of body heat. Excessive heat is eliminated by conduction, convection and radiation from the body surface. Evaporation of body moisture is also a factor. Increase in the rate of respiration, dilatation of the peripheral vessels, and reduction of heat by lessening the metabolic rate are to be included as factors in the regulatory mechanism. The body protects itself from cold through a constriction of the peripheral vessels and with an increase in general body metabolism.

Contrary to popular belief, the body temperature is not constant. Neither are all the various tissues and regions of the body held at the same temperature. Bazett (8) points out that blood has a different temperature in different regions of the body. He speaks also of temperature gradients within the body and says that when the homiothermic animal comes in contact with new temperature conditions, new temperature gradients are set up throughout the body.

Physiological research has demonstrated the effect of temperature variations on the acid-base equilibrium of the blood as well as of the tissues. Temperature alterations are known also to affect the pulse rate, circulation, blood volume, vasomotor phenomenon, and general level of metabolism. As yet, physiologists are unable to describe completely the nature of the mechanism which regulates body temperature. Barbour (6) believes that in the base of the brain there must exist a nervous mechanism corresponding to a thermostat. He shows that the rectal temperature in rabbits is lowered when the region of the corpus striatum is warmed. The opposite effect is noticed when this region is cooled. Bazett (8) believes the probable location of the center or centers which control temperature to be in the thalamus, hypothalamus, or tuber cinereum. He suggests that the center might be stimulated by the actual temperature of the blood supplying it; however Bazett emphasizes evidence to the effect that

this type of control is not the only factor in temperature regulation.

Petersen (76) reports studies which show an increase in cardiac activity, rate, and tone with colder temperatures. The opposite effect is noticed with higher temperatures. He further points out that in general the effects of cold correspond to the ARS phase, and the effects of warmth correspond to the COD phase. Adolph (2) reports that exposure to high temperatures increases CO_2 loss; thus the CO_2 tension is lowered; the H ion concentration is increased, and an excretion of alkali from the blood thereby occurs. Working with dogs, Barbour (5) finds that cold increases the red cell count, hemoglobin content, and viscosity of the blood, whereas heat decreases it. He finds also that the blood volume in the brain is increased in a cold bath and decreased in a warm bath. Barbour, Dawson, and Neuwirth (7) find that warm temperatures make for a mobilization of water, salts, and lipoids in the blood. They find, among other changes, that the blood volume is increased by the addition of water at warm temperatures. Lozinsky (39) reports that within certain body temperature ranges, dogs regulate body temperature by blood dilution.

It is pointed out by Petersen that, in general, the effect of cold involves sympathetic stimulation, especially adrenal effect. Stoland and Kinney (81) kept albino rats

at 32°, 25°, and 18° C and administered .2 gm. desiccated thyroid each day. The 32° series lived 7.3 days; the 25° series, 22 days; and the 18° series more than 32 days. They conclude that external temperature is a very important factor in determining the toxicity reaction to the thyroid gland administration. Djelineo (17) found that the BMR of rats adapted to lower temperatures was higher than that for the rats adapted to a higher temperature. At 0° C and 31° C, the ratio of the BMR was 2:1.

Hoge (26), working on a different aspect of this problem, suggests that the development of structural deviations in flies are due to some extent to temperature. She points out that the maintenance of a low temperature throughout the larval life was necessary for the production of a large proportion of physical variations.

With respect to the present study it is well to keep in mind the general physiological characteristics of animals living under different temperature conditions. Considering the picture briefly, cold temperatures seem to make for increased metabolic rate, increased peripheral vasomotor constriction, shift of the pH to the alkaline side, increased sympathetic stimulation, increased irritability of the muscles, increased mucous membrane secretion, increased blood supply to the viscera and lungs, increased production of glycogen, and increased efficiency in its utilization. In warm temperatures the physiological status, in general, shifts

to the opposite pole; namely, lower metabolic rate, decreased peripheral vasomotor constriction with an increase in blood supply to the periphery, diminished gastro-intestinal activity together with a decrease in blood supply to the viscera, shift of the pH to the acid side in the blood and body tissues, and decreased muscular activity and muscular tonicity. While the physiological and pathological implications of these two pictures are extensive and far-reaching, the present study is interested mainly in the concomitant psychological characteristics.

The experimental studies of Sumner (83, 84), Przibram (78), Sundstroem (85, 86), Mills (47, 67), and Ogle (71, 72, 73, 74) have disclosed large differences in laboratory animals reared in different temperatures. Sumner, working with white mice, began a series of experiments in 1906. These were discontinued in 1911, and up to that time some 1300 animals were used. Sumner raised colonies of mice in two rooms of different temperatures. In one room, located in an unheated building, the temperature fluctuated around an average of $43^{\circ} - 48^{\circ}$ F. The other room was heated by a steam radiator and the temperature was held near an average of $75^{\circ} - 80^{\circ}$ F. Although the conditions in this experimental set-up were not well controlled, the results are interesting and significant in view of the present study. In general, Sumner found that mice reared in the colder temperatures had shorter tails, shorter leg and foot lengths, and a greater amount of hair than the mice reared in the warm room.

He believes that his results demonstrate those modifications which have long been known to differentiate northern from southern races of mammals. Sumner observed no weight differences between the two groups. He believes also that his studies serve as proof of the transmission of acquired characteristics. In this connection he moved young to another temperature and found that they showed signs of keeping the induced characteristics.

Przibram (78) also found large differences in rats reared in different temperatures. His experimental set-up was much more elaborate and much better controlled than that of Sumner. Przibram used two rooms, one for temperatures below 20°C , and one for temperatures above 25°C . In each room he had 4 cabinets with temperatures 5 apart; thus he had 8 groups of rats in all, living at temperatures ranging from 5°C to 40°C . In considering the characteristics of rats raised in the cabinets of higher temperatures as compared with those raised in lower temperature levels, Przibram reports relatively shorter tails, and shorter legs, less massive skulls in the males, and thinner hair. Przibram states also that upon transferring to another temperature the offspring of rats raised in one temperature there appears "a reduced but distinct reminiscence of the tail-length that had been induced by heat or cold in the parents". This, he points out, occurs only when the two temperatures differ no more than 5°C , and when the parents have not been bred for

more than two generations in the first condition. However if rats raised in two temperatures 20° C apart from each other are transferred to the common middle temperature, the offspring of the cold series will grow longer tails than those of the warm series living in the same common temperature. Przibram's results disclose a higher body temperature as one proceeds from rats in the coldest to those in the warmest cabinets. He points out further that for every 5 degrees change in external temperature, body temperature varies $3/4$ of a degree. Przibram concludes that the length of the tail is conditioned by the internal body temperature value. He reports a study by Bierens de Haan in which it was found that by lowering the body temperature of young rats through the use of antipyretics, pyramidone or quinine, the tail length was diminished without actually having kept the animals in a lower temperature.

Przibram believes that his results verify the functioning of Van't Hoff's principle in physiological reactions. He suggests further that physiological modification is primarily a change in metabolic rate.

The extensive work of Sundstroem (85, 86) is also pertinent to the present study. He has been interested primarily in the physiological effects of tropical climate. Sundstroem used white mice as experimental animals and reared colonies in two rooms, one in which tropical conditions prevailed, the other, a control room in which ordinary

room temperature was maintained. In general, his results confirm those of Sumner and Przibram. However besides taking tail, body, and leg length measurements, he made observations with respect to the detailed physiological effects of tropical heat. In certain internal organs such as the liver, spleen, kidneys, and testes, the animals living in humid heat exhibited an average reduction of 20% in relative weight. Sundstroem considers especially significant the reduction in size of the thyroid which was about half as large as that of the controls. He confirms the observations made by others that the BMR is decreased in the hot group. He points out further that because of forced heat regulation, the skin receives a blood supply up to 50 times the normal; thus the supply to the internal organs is lessened. Sundstroem suggests that this may account for the smaller organs as well as for the accentuated growth of certain peripheral parts in the animals living in hot temperatures.

He finds the water content of the blood cells increased as well as a more diluted blood plasma in the hot group. In animals living in tropical conditions, he finds the blood sugar occupying a relatively low level and suggests that higher temperatures cause an increase in the urea and amino acid fractions, but cause a decrease in total creatinin, uric acid, and nucleotide nitrogen. There is also a decrease in phosphorus content of the blood which

Sundstroem believes is one of the more important effects of the tropical climate. In the higher temperatures "blood fat" is decreased. The hot rats exhibited 10% more red corpuscles than the controls, but the former showed a definite leucopenia.

Mills (47-67) and Ogle (71, 72, 73, 74) have carried out a series of elaborate experiments, the results of which disclose many facts concerning the dominance of climate over growth and development. Besides observations of gross body shape and size, many detailed physiological measurements were made.

One series of experiments reported by Mills (47) was carried out using white mice as experimental animals. Two rooms equipped with a mechanism for temperature regulation were constructed. The temperature of one room was brought to the level of stimulating coolness (65° - 70° F.), and in the other the temperature was raised to the level of tropical warmth (89° - 92° F., and 60-70 percent relative humidity). A colony of mice was reared in each of the two rooms. Wide differences in physical characteristics were observed. Speaking of these differences Mills says,

"In stimulating coolness they are born in large litters of lusty, highly-viable young, grow most rapidly, and mature earliest. Sexual cycles start early, and the onset of fertility quickly follows. Immediate conception follows almost every adult mating and the young born are of greater individual size and of larger numbers to each litter than occurs under less invigorating climatic conditions."

"In moist, tropical warmth growth is greatly re-

tarded and maturity much delayed . . . In moist heat the mice are smaller at birth, grow more slowly and reach a smaller adult size than takes place in a cooler environment. The sexual cycles begin definitely later and fertility onset is still more retarded. Many apparently healthy females raised in the heat never conceive, although mated repeatedly with outside normal males of known high fertility . . . These hot room females that do conceive, give birth to small litters of puny young, many being born dead or dying within the first week of life." (p. 20)

Along with these differences, it was observed that the hot room mice had the shortest bodies and the longest tails--approximately 1 cm. longer. Ogle (72) suggests that these differences are the result of changes in the thyroid-pituitary functions brought about by temperature and humidity conditions.

Mills suggests an optimum temperature for the mouse, near 70° F, and points out that if the environmental temperature rises above or falls below this optimum, the effect of growth depression appears.

Mills believes that the endocrine system is particularly responsive to climatic stimulation. In this connection Ogle (71) has made detailed studies of the effect of temperature on variations in sexual function. She found degeneration and giant cell formation in the germinating epithelium of male mice raised in hot humid temperatures. Mice raised in a cool, stimulating temperature exhibited intra-abdominal testes having active germinal tissue. When such males were transferred to humid heat, an abrupt degeneration of the testes took place. These microscopic examinations of the testes

support the contention that fertility is affected by changes in environmental temperature level.

Ogle and Mills (74) also report the age at the opening of the vaginal plate in the female white mouse. In 32 females living in humid heat the vaginal plate opened about 4 days later than was the case in the cold room animals.

Using rabbits instead of mice, Ogle and Mills (73) have demonstrated that animals living in cool temperatures (52° - 56° F) are able to stand prolonged chilling better than those adapted to higher temperatures (88° - 92° F). It was found also that the animals adapted to higher temperatures were able to withstand high temperatures (110° F) in a water bath better than those from the cold room. Their results indicate further that upon prolonged chilling, the cold room animals more freely utilized glycogen in maintaining body temperature. The hot room animals die before more than a small amount of the stored glycogen is used. This is attributed to the general low level of combustion in the hot room group. The cold room animals exhibited a heightened resistance to infection; whereas the hot room animals easily succumbed to infections.

Mills considers the ease of body heat loss the basic factor in determining the general metabolic level of homeothermic animals. This conclusion is logical, he believes, because energy for all bodily functions is a product of combustion. As pointed out in the previous discussion, Mills and Ogle have demonstrated this principle to be basic to

such bodily functions as speed of growth and development, regulation of body size and shape, and maturation in sexual function and fertility. In general, they have shown that moist heat lowers the metabolic level, but a cool temperature raises it.

In order to be certain that this metabolic depression in higher temperatures and the stimulating effect of cooler environments were not the result of breathing warm air and cold air respectively, Mills and Ogle (65) used another experimental set-up in which the heat loss was controlled through the use of radiant channels. Their set-up for this consisted of four rooms. In room 1, an air temperature of $89^{\circ} - 92^{\circ}$ F was maintained. Room 2 was kept at the same atmospheric temperature level ($89^{\circ} - 92^{\circ}$ F), but it was lined with aluminum foil and contained 6 cold plates which were kept at a temperature of $32^{\circ} - 40^{\circ}$ F. Room 3 was lined with aluminum foil but was also equipped with a source of radiant heat. The air temperature in this room was held at $70^{\circ} - 76^{\circ}$ F. Only in room 4 was the atmospheric temperature controlled, this being maintained at $66^{\circ} - 70^{\circ}$ F. Groups of mice raised at ordinary room temperature were introduced into the four test rooms. Weekly weight records and fertility records were taken. The mice in room 1 exhibited retarded growth and development. A retardation in growth took place also in room 3 in spite of the fact that the air temperature was $70^{\circ} - 76^{\circ}$ F. The mice in room 2 displayed the most rapid

growth and earliest sexual development. Concerning these results, Mills and Ugle say (65),

"There now remains little doubt that general metabolic level is dominated by the ease with which body heat can be lost. The depressing effects of atmospheric moist heat can be completely overcome by properly facilitating body heat loss through radiant channels alone. This holds either in animal experiments or in human comfort. Likewise, the stimulation of cool surroundings, can be turned to depression by increasing the radiant heat load on the organism. It thus becomes evident that the avenue of heat loss is unimportant,--it is the actual net rate of loss that serves to limit the general metabolic level of the individual." (p. 39)

Since temperature is a very important factor relative to the physiological status of an organism, it follows that certain psychological alterations should follow upon variations in temperature. A search through the literature reveals few well controlled experimental studies of the effect of temperature on the behavior of the organism. And at most, the work that does concern this problem is quite definitely limited to cold blooded animals. In this connection the work of Crozier (15) and Hoagland (25) should be mentioned. Hoagland studied the speed with which ants learned a maze under different temperatures. He found the rate of learning to be unaffected by temperatures within the range from 15° to 25° C; however within the range of 25° to 29.4° C, he found a 100% acceleration, provided the duration of the high temperatures was not too long. In addition he studied retention after 18 hours and found it to be unaffected by temperatures under 25° C, but he found that after exposures of 18 hours

at 28.3° or 29.4° C, the ants not only forgot the solution, but took many more than the initial number of trials to re-learn it.

Wever (89) demonstrated that water temperature, as an incentive, is a factor in swimming activity in the rat. He measured the time taken by the rat to swim from one end of a tank of water to another and found that the incentive for escape was greatest for low temperatures and least when the water temperature was near that of body temperature. Wever says that high temperatures "produce considerable stimulation, but apparently of a disorienting character, resulting in a relatively inadequate performance". He finds also that relatively low temperatures (20° C approximately) "provide a comparatively constant and reliable incentive and are therefore recommended for use in water-maze studies".

Hack (20), concerned with the same problem, used water temperatures of 15° , 37.5° , and 45° C in a simple water-maze. He reports that,

"... at a temperature of 45 the behavior was at first marked by confusion and progress was slow, but later a fairly high degree of proficiency was gained. When the temperature was 37.5° C, which is average body temperature for the rat, progress was slow and highly irregular, and, within the limits of the experiment, the rats failed to attain the level of proficiency shown by the other two groups."

Hack concludes that learning in this situation is in part a function of water temperature.

Heron (23) reports that there is a tendency for better learners (rats) to have a higher basal metabolism.

CHAPTER III

EXPERIMENTAL CONDITIONS

The purpose of this experiment was to determine the nature and extent of the physical and behavioral differences exhibited by rats reared under different temperatures. That portion of the present project which deals with the problem of physical and morphological differences derives its importance as a contribution largely through its confirmatory nature since much research has been done by others relative to the climatic influence on growth and development. In the main, this study is concerned with behavioral differences, and more specifically, with those differences as measured by maze learning. The physical measurements which were taken are secondary to the main purpose of the thesis.

Three rooms were constructed, insulated with one inch Insulite. The rooms were of slightly different shape and dimensions; however each was approximately six feet square and seven feet high. An electric heater controlled by a thermostat held the temperature of one room at 89° to 92° F. The air in this room was kept around 50% saturation by an electric fan which blew a constant stream of air over a heated, shallow pan of water. This facilitated evaporation and provided a constant movement of the air within the room. Another was equipped with a Frigidaire refrigeration unit which maintained a temperature level of 55° to 58° F. The air in this room was kept relatively dry by the dehydrating action.

of the condensing unit in the room. The fan in the condensing unit provided air movement in this room similar to the air movement in the hot room. The temperature and humidity of the third room were allowed to fluctuate with the ordinary atmospheric conditions of the building. During the first 3 months of the experiment the temperature of this room fluctuated above and below a mean of 83° F, and during the latter 6 months the temperature of this room fluctuated above and below a mean of 76° F. No measures were made relative to the moisture content of the air in this room. Here an electric fan provided air movement similar to that in the other two rooms.

Each room was equipped with steel cage-stands and cages of $\frac{1}{8}$ in. mesh hardware cloth with removable zinc tops and bottoms. Sawdust and excelsior were used as cage bedding in the cold rooms. Drop-tube bottles provided a constant supply of water to the cages.

Thirty white albino female rats were bred and brought to the date of parturition in a large room, the temperature of which fluctuated with the temperature of the rest of the building. Hereditary information relative to these original females was unavailable; however they were of good stock and were large, healthy animals. At 28 days of age, each litter was divided into three equal groups; one group was caged in the cold room, another in the control room, and the third

group was placed in the hot room. At this time each rat was weighed and numbered with an ear mark. The rats were numbered by rooms; for example, in litter number one there were six individuals, and the two which were placed in the cold room were numbered 1C, and 2C; the pair placed in the control room were numbered 1X and 2X; the remaining two which were placed in the hot room were numbered 1H and 2H. The thirty original females produced 213 young; thus 71 rats were provided for each of the three experimental rooms. Weekly weight measures were made of each rat throughout the experimental period. Diet was controlled by keeping a supply of Purina Fox Chow dog biscuits in all the cages at all times. In addition to this the rats were fed lettuce once a week.

Some of the females in each of the three rooms were allowed to breed as soon as maturity was reached. At 28 days of age, the young of this second generation were weighed, and numbered with ear marks, and were kept in the rooms in which they were born. Weekly weight records of each individual rat in this second generation were kept.

In both the first and second generations the rats were killed when they were 21 weeks of age. At this time body-length and tail-length measurements were made. The animals were killed with chloroform, and immediately thereafter the rat was laid on its back and extended to its full length. The tail was drawn out straight. With calipers the distance

from the tip of the nose to the tip of the tail was taken and its value in centimeters was found by setting the points to a scale. The distance from the tip of the tail to the center of the anus was found and its value was determined in the same way. These measurements gave, first, the total length, second, the tail length and by the difference, the body length.

Three, four-alley, standard mazes of identical material and dimensions were constructed. The alleys were 3 in. wide and 4 in. high. The top was covered with $\frac{1}{4}$ in. mesh hardware cloth and all parts of the maze were painted black. Figure III is a diagram of the maze.

FIGURE III
DIAGRAM OF THE MAZE

This maze pattern has been used by Lashley (37) in

his brain extirpation experiments. Shirley (80) determined its reliability. She found the odd vs. even correlation to be $+ .62$, $+ .055$ for errors and $+ .84$, $+ .039$ for time. She reports evidence to show that trials, errors, and time are consistent criteria for learning. She obtained correlations of $+ .93$, $+ .018$ between time and errors; $+ .90$, $+ .025$ between trials and errors; $+ .57$, $+ .092$ between time and trials.

The mazes were constructed with a substantial bottom which made it possible to move them about easily. The mazes were set up in the rooms each day that the rats were run. After the running period for the day the mazes were removed. In order to control lighting, the mazes were equipped with a fixture which supported a 40 watt light 2 feet directly above the maze; thus light was supplied to each maze from the same angle. The sliding doors of the starting box and food box were operated by means of a string-pulley system outside the room. A glass window in the door of each room permitted the experimenter to observe the progress of the rat in the maze. Operating the mazes from without not only removed the factor of the experimenter's presence, but also reduced auditory disturbances to a minimum since the rooms were relatively sound proof.

At 80 to 95 days of age, rats from all the rooms were started on the initial training in the maze. Approximately 45 rats from each room were used as subjects for the maze

situation. Approximately $2/3$ of the maze subjects from each room were males; the remaining $1/3$ were females. In order to differentiate between the effect of the temperature of the room in which the rat learned the maze and the effect of the temperature of the room in which the rat was raised, it was decided to have a third of the rats from each room run the maze in one of the three temperature conditions; for example, a third of the cold room rats learned the maze in the cold room, another third of the cold room rats learned the maze in the control room, and the remaining third of the cold room rats ran the maze in the hot room. The maze subjects from the control and hot rooms were divided and shifted in the same manner for the maze learning. Therefore there were altogether 9 groups of maze subjects--three groups from each room.

In the following portions of this report, the various groups of maze subjects will be referred to in terms of letter-symbols. H, X, and C will be used to represent rats that were reared in the hot, control, and cold rooms, respectively; h, x, and c will refer to the hot, control, and cold rooms, respectively; thus a symbol Hh will be used to refer to those rats who were raised in the hot room and who learned the maze in the hot room. Similarly, Cx will be used in referring to those rats who were reared in the cold room but learned the maze in the control room.

In the maze situation, Gains Dog Meal mixed to a paste

with condensed milk was used as the incentive. The rats were deprived of food for 24 hours before the initial trial in the maze. After the animals had completed their runs for the day, they were placed in their home cages and were allowed to feed for one hour on the same food mixture as was used in the maze. After the elapse of this period of time, the food was removed and the rats were not fed again until the completion of the runs on the subsequent day.

Records of time, errors, and trials were kept on each rat. An entrance into a blind alley beyond the shoulders of the rat was counted as an error. The number of errors in back-tracings was determined by the number of back units into which the rat proceeded. The criterion of learning was fixed at three consecutive errorless runs.

Each rat was given one trial the first day, three trials the second and third days, and five trials a day from then on until the 37th trial at which time he was given 10 trials per day. The running was discontinued at 100 trials in the case of those rats which had not mastered the maze at this point. During the initial trials in the maze, a 30 minute time limit was set. If the rat had not completed the run in this time, it was removed and placed in the food box. Here it was allowed to eat for 30 seconds and was then started on another trial. After 5 consecutive incomplete runs, the rat was removed from the experiment.

Thirty days after having learned the maze, each rat was

tested for retention by relearning the maze. In the relearning situation, the rat was given 3 trials the first day, five trials the second day, and ten trials each day thereafter until it relearned the maze. The criterion of learning in the relearning situation was the same as for original learning, namely, three consecutive errorless runs. During the initial trials in the retention situation, a 15 minute time limit was set. After 5 consecutive incomplete runs the rat was removed from the experiment.

All maze training was done during the afternoon and early evening. The experimenter ran a large percentage of the rats himself; however a portion was done by assistants who were carefully instructed and trained relative to the manner of handling the rats, counting errors, and taking time measurements. All possible precautions were taken to see that each assistant handled the rats in a manner comparable to previously set standards. During the time when rats were being run by assistants, their work was under the constant supervision of the experimenter.

The entire experimental procedure was repeated with an equal number of second generation subjects. With both the first and second generations, identical conditions were maintained throughout the period of experimentation.

CHAPTER IV

RESULTS

In many instances a rigorous statistical manipulation of data results in artifacts, misrepresentations, and inadequacies. The important phenomenal characteristics of a series of events may or may not be represented adequately through the use of statistical procedures, and it is sometimes true that statistical applications aid little in the exposition of data. On the other hand, many times it is impossible to describe the true status of data except through the use of statistics. When to use, and when not to use these techniques is a question of paramount importance. An intensive evaluation of statistical usage is beyond the scope of the present study; however, since relatively extensive use will be made of certain of these measures in paragraphs to follow, it is well to point out at the onset that the limitations just mentioned have been taken into consideration.

The fact that statistical measures will be lacking in the treatment of some of the data to follow is another reason for raising the question. In other words, these problems were brought up in order to explain why averages, standard deviations, standard errors, and critical ratios were determined in some cases and were not determined in others. Some of the measures which were figured may exhibit no immediate usefulness; however the primary reason for determining these

particular measures was to make them available for immediate use in case they prove to be desirable.

In this chapter are presented the data of the experiment. They show in general that temperature is an important variable in the influencing of growth and morphological characteristics of white rats. Furthermore this chapter contains detailed and extensive data on the relationship of temperature to the behavioral characteristics of the white rat. No attempt will be made, however, to show more than relatively gross differences between experimental groups. Growth and morphological characteristics will be considered first. A discussion of differences in behavior will follow.

In considering the physical differences exhibited by rats from the hot, control, and cold rooms, respectively, it can be said, in general, that those animals living in temperature conditions which facilitate the loss of body heat grew much more rapidly and reached a larger adult size than did those animals living under less stimulating temperature conditions. With reference to the first generation, Figures IV, V, VI, and VII illustrate the difference in size of representative rats from the hot, cold, and control rooms, at 21 weeks of age. Figures VIII and IX show that this difference at 21 weeks of age is the result of a difference in rate of growth. The growth curves show clearly that growth and development are influenced by temperature. The curves

REPRESENTATIVE FIRST GENERATION MALES AT 21 WEEKS OF AGE
FROM THE COLD AND HOT ROOMS

FIGURE V

REPRESENTATIVE FIRST GENERATION MALES AT 21 WEEKS OF AGE
FROM THE CONTROL AND HOT ROOMS

FIGURE VI

REPRESENTATIVE FIRST GENERATION MALES AT 21 WEEKS OF AGE
FROM THE CONTROL, COLD, AND HOT ROOMS

FIGURE VII

REPRESENTATIVE FIRST GENERATION FEMALES AT 21 WEEKS OF AGE
FROM THE CONTROL, COLD, AND HOT ROOMS

FIGURE VIII

GROWTH CURVES OF THE FIRST GENERATION MALES

FIGURE IX

GROWTH CURVES OF THE FIRST GENERATION FEMALES

for the first generation suggest little difference in rate of growth between the cold and control room rats; however the curve which represents the rate of growth of those rats living in the hot room lags far behind the curves for those animals living in the more favorable conditions of the control and cold rooms.

As illustrated in Figures X, XI, XII, XIII, XIV, and XV, a more striking difference becomes apparent in comparing the size of representative second generation animals from the cold, control, and hot rooms, respectively. In this instance the rats from the cold room showed a decided advantage in terms of body size over both the control and hot room rats. It is apparent from the growth curves for the second generation (Figures XVI and XVII) that the rats which were born and reared in the cold room were already significantly larger at 4 weeks of age. Although definite quantitative data are unavailable, it was observed that, at birth, rats born in the cold room were of greater individual size than were those which were born either in the control or the hot room. It was observed further that, at birth, the rats born in the control room were of greater individual size than those which were born in the hot room. The irregularities which appear in the growth curves at about the 8th week are probably associated with the fact that the rats were deprived of food for maze running at this time.

FIGURE X

REPRESENTATIVE SECOND GENERATION MALES AT 21 WEEKS OF AGE
FROM THE COLD AND HOT ROOMS

FIGURE XI

REPRESENTATIVE SECOND GENERATION MALES AT 21 WEEKS OF AGE
FROM THE CONTROL AND HOT ROOMS

FIGURE XII

REPRESENTATIVE SECOND GENERATION MALES AT 21 WEEKS OF AGE
FROM THE CONTROL, COLD, AND HOT ROOMS

FIGURE XIII

REPRESENTATIVE SECOND GENERATION FEMALES AT 21 WEEKS OF AGE
FROM THE COLD AND HOT ROOMS

FIGURE XIV

REPRESENTATIVE SECOND GENERATION FEMALES AT 21 WEEKS OF AGE
FROM THE CONTROL AND HOT ROOMS

FIGURE XV

REPRESENTATIVE SECOND GENERATION FEMALES AT 21 WEEKS OF AGE
FROM THE CONTROL, COLD, AND HOT ROOMS

FIGURE XVI

GROWTH CURVES OF THE SECOND GENERATION MALES

FIGURE XVII

GROWTH CURVES OF THE SECOND GENERATION FEMALES

One may observe, in comparing the growth curves for the first and second generations, that the effect on growth and adult size of conditions which facilitate the loss of body heat is even greater in the second generation than it is in the first (Figures VIII and IX, XVI and XVII). The cold rats of the second generation grew more rapidly and reached a larger adult size than did the cold rats of the first generation. The rate of growth of the cold room rats of the second generation surpassed that of the control room rats of the second generation. This is not the case, of course, in comparing the rate of growth of the cold room rats of the first generation with that of the first generation control room rats. On the contrary, in this case those differences which did exist were slightly in favor of the control room animals. Another interesting and significant fact may be noted if one compares the growth curves of the first and second generation hot room rats. In this instance it appears quite evident that the individuals of the second generation were of even smaller size than those of the first generation. In the process of adapting to the warm temperature, the second generation hot room rats developed even more slowly than did those of the first generation. The difference in body size between the two generations is present from the time of birth on.

The more favorable effect of cooler temperatures appears to be accumulative from the first generation to the second; likewise the depressing effect on growth of warm

moist conditions seems to increase from the first to the second generation. At what point, under those two conditions, the rate of growth might have stabilized, remains yet to be answered by further experimentation. This study was carried only through the second generation.

Significant morphological differences accompany the growth differences. In adapting to different temperature conditions, the organism controls and regulates the relative growth rate of various body structures. In a rather concrete fashion this regulation is demonstrative of an "economy principle". That is, the body shape of animals living under conditions of depressing heat is modified and adjusted in the course of maintaining the most efficient avenues through which body heat may be lost. Different morphological characteristics are exhibited by animals which live in cool, and more enervating temperatures. The organism is then primarily concerned with conserving its body heat. This results, of course, in a body shape which is conducive to preserving body heat.

Apparently, the long slender body is the most efficient shape for maintaining the proper channels for body heat loss. On the other hand, the short spherical body form appears to be the most efficient in preserving body heat. Those animals reared in the hot room had relatively longer, more slender bodies, longer tails, longer legs, and larger ears than the animals raised in the stimulating coolness of the cold room.

The rats from the hot room appeared to have less massive skulls, less hair, and, in general, a more delicate bone structure than had those from the cold room. The testicles of the males from the hot room were suspended in a relaxed and extended scrotum, the posterior half of which was devoid of hair. Quite the contrary was characteristic of the cold room males. In these animals the testicles were held near the body in a scrotum which was well protected with hair.

In order to differentiate this picture further, definite body measurements were made. Tables I and II illustrate typical differences which were found among the three groups. Absolute differences in body length, weight, and tail length are significant. In order to arrive at a more representative means of describing the differences, two ratios were used; namely, body weight: body length, and body length: tail length. The weight in grams per running centimeter of body length is obtained by using the body length: body weight ratio. This ratio is quite descriptive of the general body shape, that is, the long and slender versus the short and plump pattern. The second ratio, body length: tail length, gives a measure which is more descriptive of group differences in tail length and body length than are absolute measurements.

As can be observed by examining Tables I and II, both males and females, living in cooler temperatures have shorter tails, more weight per running centimeter of body length, and are heavier than those living in less stimulating temper-

TABLE I

THE MEAN BODY LENGTH, WEIGHT, TAIL LENGTH, BODY WEIGHT:
BODY LENGTH RATIO, AND BODY LENGTH: TAIL LENGTH RATIO
OF THE FIRST GENERATION MALES AT 21 WEEKS OF AGE FROM
THE COLD, CONTROL AND HOT ROOMS

Gr- oup	No.	Mean body L.	Mean Wt.	Mean Tail L.	Body weight Body length			Body length Tail length		
					Mean	σ	$\frac{\sigma}{\sqrt{N}}$	Mean	σ	$\frac{\sigma}{\sqrt{N}}$
C	31	20.9	273	16.7	13.1	1.305	.2344	1.25	.0498	.0089
X	32	20.5	279	18.4	13.6	1.294	.2287	1.12	.0616	.0109
H	32	19.9	246	17.7	12.4	.891	.1575	1.12	.0518	.0091

TABLE II

THE MEAN BODY LENGTH, WEIGHT, TAIL LENGTH, BODY WEIGHT:
BODY LENGTH RATIO, AND BODY LENGTH: TAIL LENGTH RATIO
OF THE FIRST GENERATION FEMALES AT 21 WEEKS OF AGE FROM
THE COLD, CONTROL, AND HOT ROOMS

Gr- oup	No.	Mean body L.	Mean Wt.	Mean tail L.	Body weight Body length			Body length Tail length		
					Mean	σ	$\frac{\sigma}{\sqrt{N}}$	Mean	σ	$\frac{\sigma}{\sqrt{N}}$
C	31	18.2	186.5	15.8	10.3	1.038	.1864	1.15	.0511	.0091
X	31	18.3	181.8	16.7	10.0	.7909	.1420	1.10	.0479	.0086
H	24	17.5	165.8	16.2	9.5	1.064	.2219	1.08	.0500	.0102

ature conditions. There is one exception to be noted (Table I); namely, the males from the control room have a slight advantage in body weight and in the body weight:body length ratio over the cold room males. This advantage, as will be noted subsequently, disappears in the second generation. The control rats have larger absolute tail lengths than do the hot room rats. This difference, however, vanishes when the two groups are compared in terms of the body length:tail length ratio.

The statistical reliability of these differences is shown in Tables III and IV. Here the critical ratios are sufficiently high to warrant the conclusion that reliable differences do exist.

The tail length, body length, and body weight measurements for the second generation demonstrate the influence of temperature on morphological characteristics in even a more striking fashion (Tables V and VI). In general, these measurements reveal the same type of morphological characteristics as do the measurements of the first generations; however, as in the case of growth, the differences become wider from the first generation to the second. In Tables IX and X a comparison is made of the body measurements of the two generations. This table demonstrates that the second generation cold room rats have shorter tails and have more weight per running centimeter of body length than do the first generation cold room rats. The second generation hot room rats have

RELIABILITY (CRITICAL RATIOS) OF THE DIFFERENCES IN BODY WEIGHT: BODY LENGTH AND BODY LENGTH: TAIL LENGTH RATIOS AMONG THE FIRST GENERATION MALES FROM THE COLD, CONTROL, AND HOT ROOMS

<u>Body wt.</u> <u>Body L.</u>					<u>Body L.</u> <u>Tail L.</u>			
Pair	Mean	Diff.	σ Diff.	C.R.	Mean	Diff.	σ Diff.	C.R.
C	13.1	.5	.327	1.53	1.25	.13	.0141	9.22
X	13.6				1.12			
C	13.1	.7	.282	2.48	1.25	.13	.0128	10.16
H	12.4				1.12			
X	13.6	1.2	.278	4.32	1.12	0	.0142	0
H	12.4				1.12			

TABLE IV

RELIABILITY (CRITICAL RATIOS) OF THE DIFFERENCES IN BODY WEIGHT: BODY LENGTH AND BODY LENGTH: TAIL LENGTH RATIOS AMONG THE FIRST GENERATION FEMALES FROM THE COLD, CONTROL, AND HOT ROOMS

<u>Body wt.</u> <u>Body L.</u>					<u>Body L.</u> <u>Tail L.</u>			
Pair	Mean	Diff.	σ Diff.	C.R.	Mean	Diff.	σ Diff.	C.R.
C	10.3	.3	.234	1.28	1.15	.05	.0126	3.95
X	10.0				1.10			
C	10.3	.8	.289	2.77	1.15	.07	.0137	5.11
H	9.5				1.08			
X	10.0	.5	.263	1.90	1.10	.02	.0133	1.50
H	9.5				1.08			

TABLE V

THE MEAN BODY LENGTH, WEIGHT, TAIL LENGTH, BODY WEIGHT:BODY LENGTH RATIO, AND BODY LENGTH:TAIL LENGTH RATIO OF THE SECOND GENERATION MALES AT 21 WEEKS OF AGE FROM THE COLD, CONTROL, AND HOT ROOMS

Group	No.	Mean Body L.	Mean Wt.	Mean Tail L.	Body Wt. Body L.			Body L. Tail L.		
					Mean	σ	$\frac{\sigma}{\sqrt{N}}$	Mean	σ	$\frac{\sigma}{\sqrt{N}}$
C	33	21.1	284	16.2	13.2	.852	.1671	1.30	.0562	.0098
X	30	21.2	271	17.9	12.8	.899	.1669	1.18	.0381	.0070
H	16	19.6	200	18.0	10.2	1.200	.3337	1.09	.0129	.0035

TABLE VI

THE MEAN BODY LENGTH, WEIGHT, TAIL LENGTH, BODY WEIGHT:BODY LENGTH RATIO, AND BODY LENGTH:TAIL LENGTH RATIO OF THE SECOND GENERATION FEMALES AT 21 WEEKS OF AGE FROM THE COLD, CONTROL, AND HOT ROOMS

Group	No.	Mean Body L.	Mean Wt.	Mean Tail L.	Body Wt. Body L.			Body L. Tail L.		
					Mean	σ	$\frac{\sigma}{\sqrt{N}}$	Mean	σ	$\frac{\sigma}{\sqrt{N}}$
C	28	19.1	208	16.1	10.9	1.056	.2071	1.19	.0431	.0081
X	24	18.8	190	16.5	10.1	.627	.1280	1.14	.0386	.0079
H	11	18.2	140	16.1	7.7	.797	.2410	1.13	.0206	.0062

TABLE VII

RELIABILITY (CRITICAL RATIOS) OF THE DIFFERENCES IN BODY WEIGHT:
BODY LENGTH AND BODY LENGTH:TAIL LENGTH RATIOS AMONG THE SECOND
GENERATION MALES FROM THE COLD, CONTROL, AND HOT ROOMS

Pair	<u>Body Wt.</u> <u>Body L.</u>				<u>Body L.</u> <u>Tail L.</u>			
	Mean	Diff	σ Diff	C.R.	Mean	Diff	σ Diff	C.R.
C	13.2	.4	.236	1.70	1.30	.12	.0100	12.00
X	12.8				1.18			
C	13.2	3.0	.372	8.07	1.30	.21	.0104	20.19
H	10.2				1.09			
X	12.8	2.6	.372	6.99	1.18	.09	.0078	11.54
H	10.2				1.09			

TABLE VIII

RELIABILITY (CRITICAL RATIOS) OF THE DIFFERENCES IN BODY WEIGHT:
BODY LENGTH AND BODY LENGTH:TAIL LENGTH RATIOS AMONG THE SECOND
GENERATION FEMALES FROM THE COLD, CONTROL, AND HOT ROOMS

Pair	<u>Body Wt.</u> <u>Body L.</u>				<u>Body L.</u> <u>Tail L.</u>			
	Mean	Diff	σ Diff	C.R.	Mean	Diff	σ Diff	C.R.
C	10.9	.8	.243	3.29	1.19	.05	.0113	4.43
X	10.1				1.14			
C	10.9	3.2	.318	10.06	1.19	.06	.0102	5.88
H	7.7				1.13			
X	10.1	2.4	.273	8.79	1.14	.01	.0101	9.90
H	7.7				1.13			

TABLE IX

RELIABILITY (CRITICAL RATIOS) OF THE DIFFERENCES IN BODY WEIGHT:BODY LENGTH AND BODY LENGTH:TAIL LENGTH RATIOS BETWEEN THE FIRST AND SECOND GENERATION MALES

Pair	<u>Body Wt.</u> <u>Body L.</u>				<u>Body L.</u> <u>Tail L.</u>			
	Mean	Diff	σ Diff	C.R.	Mean	Diff	σ Diff	C.R.
C ₁	13.1	.1	.288	.35	1.25	.05	.0132	3.79
C ₂	13.2				1.30			
X ₁	13.6	.8	.283	2.83	1.12	.06	.0129	4.65
X ₂	12.8				1.18			
H ₁	12.4	2.2	.370	5.95	1.12	.03	.0098	3.06
H ₂	10.2				1.09			

TABLE X

RELIABILITY (CRITICAL RATIOS) OF THE DIFFERENCES IN BODY WEIGHT:BODY LENGTH AND BODY LENGTH:TAIL LENGTH RATIOS BETWEEN THE FIRST AND SECOND GENERATION FEMALES

Pair	<u>Body Wt.</u> <u>Body L.</u>				<u>Body L.</u> <u>Tail L.</u>			
	Mean	Diff	σ Diff	C.R.	Mean	Diff	σ Diff	C.R.
C ₁	10.3	.6	.278	2.16	1.15	.04	.0123	3.26
C ₂	10.9				1.19			
X ₁	10.2	.1	.191	.52	1.10	.04	.0116	3.45
X ₂	10.1				1.14			
H ₁	9.5	1.8	.327	5.51	1.08	.01	.012	.83
H ₂	7.7				1.09			

longer tails and have less weight per running centimeter of body length than do the first generation hot room rats. Although one would not anticipate a difference between the first and second generation rats from the control room, nevertheless, one does appear. The tails of the second generation were slightly shorter. As was pointed out in Chapter III, the experiment was begun in mid-summer. At this time the temperature of the control room fluctuated above and below a higher average than was the case later on in the experiment. During the time when the first generation control room rats were growing most rapidly, the room temperature approximated an average of 83° F. The second generation control room rats were not born until the fall months during which time the room temperature fluctuated above and below an average of 76° F. Taking this temperature difference into consideration, one would expect the second generation to have somewhat shorter tails than the first generation.

Data from this study, relative to fertility and sexual function, support the thesis, as advanced by other experimenters in the field, notably, Mills (47,-67), Huntington (29,-35), and Petersen (76), that temperature is important in influencing (1) the age at which sexual maturity is reached, (2) size of litters, and (3) general vitality of the young. During the progress of the present experiment, it was noticed that females of the first generation living in the cooler temperatures of the cold and control rooms exhibited an average

conception date fully two weeks ahead of those females living in the hot room. There was no noticeable difference between the control and cold room females in average age at first conception. Since these observations were made only on the first generation females, it is impossible to say whether the second generation females, that is, those which were actually born in the respective rooms, would show even wider differences relative to the onset of fertility; however, in light of general observations, one would be safe in anticipating a widening of these differences in the females of the second generation.

The females from the cold and control rooms not only reached sexual maturity earlier, but also gave birth to litters of larger young than did the females from the hot room. As far as could be observed, not a single individual born in the cold room died within the first several weeks of life; whereas the mortality rate among the rats born in the hot room was extremely high. There was here a very high death rate during the first few weeks of life of the rats which were born alive, and many litters were born dead. The mortality rate among litters born in the control room was, of course, quite low; however more individuals from this room died shortly after birth than was the case in the cold room.

The fact that many seemingly healthy females in the hot room never conceived, although mated with males of proved fertility, is another interesting and very significant difference. A notable percentage of the pregnant females from the hot room died just previous to parturition. Other females

from this room were seemingly unable to supply milk for their young. This factor accounts to some extent for the high early mortality rate among the young in the hot room. Significant also is the fact that the cold room females took very good care of their young. They built well-structured nests and gave the young constant "attention"; whereas the hot room females scattered their young about the cage and paid little "attention" to them. It was not unusual for the females in the hot room to eat their young. This type of behavior never took place in the cold room.

By comparing the number of each sex which were born in the three rooms, striking differences in sex ratio were observed. No attempt was made to differentiate the sex at the time of birth--our sex ratios are based on the relative number of each sex which grew to adulthood. Because of this, the sex ratio for the hot room may not be entirely correct; however, since no individuals died in the cold room, and since relatively few died in the control room, the sex ratios for these two rooms represent the true state of affairs. The sex ratios were: hot room, 71 males to 100 females; control room, 106 males to 100 females; cold room, 156 males to 100 females. These ratios suggest a relationship between temperature and sex determination. Although many interesting speculations could be made relative to the nature of this relationship, it is beyond the scope of this study to enter into such a discussion.

The listless, sluggish, "inattentive", and "lazy" characteristics which typified the general level of activity of the hot room animals were easily observed. On the other hand, the general behavior of the cold room rats was such that terms which are descriptive of quite the opposite type of behavior need to be used. The cold room rats were very active; however, while sleeping and during times of no activity, the individuals in a cage would "huddle together" in order to preserve body heat. The control room rats behaved in a manner typical of "ordinary rat behavior". Visitors who came into the laboratory were usually surprised to find the rats in the hot room lying around in relaxed, and in many cases, grotesque positions. These peculiar and odd positions were so marked in the hot room animals that they were commented upon by a five year old child who was alarmed over their unusual characteristics. She thought the rats were dead, and she did not like dead rats.

The hot room rats offered more resistance to handling; however this difference appeared only after the animals had been handled a great deal, especially in connection with the maze situation.

It has been demonstrated that the sexual activity of the rat follows rather definite and rigidly set patterns, nevertheless, there seemed to be more "sex play" among rats living in the hot room than among the other two groups.

Thus, it turned out that physical differences between the hot and cold room rats found in this study confirm the

work of Mills (47 - 67), Przibram (78), Sundstroem (85, 86), and Sumner (83, 84).

Maze Behavior

The ease with which body heat is lost is an important variable in relation to the maze behavior of rats. Animals which were raised in the cool, stimulating temperatures of the cold room were far superior in maze performance to those reared in the high temperatures. The performance of the cold room rats was not only quantitatively superior, in terms of trials, errors, and time, to the hot room animals, but was also characterized by wide and significant qualitative differences. The performance of the control room rats was also superior to that of the animals from the hot room; however these control room animals were inferior in maze performance to the cold room rats.

As was pointed out in Chapter III, the maze subjects from each room were divided into three equal groups. Each third learned the maze under different temperature conditions; thus the performance of rats which were raised in each room was measured under three temperature conditions.

Table XI illustrates the differences which were found among the nine groups. These differences are given in terms of average time, number of errors, and number of trials required for mastery of the maze. In each criterion of performance the Cc group was superior to all the other groups. The greatest superiority is shown in the relatively fewer trials

required by the Cc group. The difference in number of errors made during learning is also, for the most part, significant. (See Table XIII). When the three groups from each room are combined (Table XVII), it can be observed that the cold room rats showed the best maze performance, with the control rats coming next. Both groups were trailed by the rats from the hot room. These differences are shown especially well in the case of trials and errors, and the differences in time are equally significant with one exception, namely, difference in time between the cold and control room rats.

Table XI, shows that regardless of the temperature in which the animal was raised, the temperature of the room in which it learns the maze influences to a considerable extent the nature of its performance. For example, the Ch group required more time and trials, and made more errors than did either the Cx or the Cc groups. In the case of the cold room rats, as the temperature level of the room in which they were run was increased, their level of performance decreased. Considering the maze behavior of the control room rats under the three different temperature conditions, a difference in level of performance is also noted. In this instance, the achievements of the Xh group was comparable to that of the Xc group. Both of these groups, however, differ significantly in performance level from the Xx group. This gives added support to the belief that rats perform best under a temperature which is nearest to that of their home room. It appears that the rats from the hot room maintained about the same level of

performance, regardless of the temperature under which they were run. There is a tendency for these animals to do more poorly in the cold room, but this difference is not statistically reliable. (Table XIII).

Another significant fact brought out by Table XI is the differences in size of the sigma for the various groups. The sigma increases as the efficiency of maze performance decreases; thus it follows that in those groups dominated by "poorer learners", there was also greater variability. This point is brought out further in Table XII. In the less proficient groups the ranges for the three criteria of learning are several times as large as they are for the more proficient groups.

Table XIII was worked out for the purpose of showing the extent to which the differences are statistically reliable when each of the nine groups is compared with each of the other eight. The highest reliability is found between the relative number of trials which each group required in order to learn the maze. The differences in average number of errors made are also significant in most cases; however the critical ratios for differences in errors did not run as large as the critical ratios for trials. In general the differences in time were less significant than was the case in both trials and errors. Even in terms of time, however, the group differences in which we are most interested are substantiated by statistically significant critical ratios.

Other differences among the nine different groups, are

found in Table XII. It can be observed from this table that the median scores for trials, errors, and time, closely approximate the average scores for these criteria. There is a tendency for the median scores for the hot room animals to be slightly below the average scores. The fact that several

TABLE XI

MEASURES OF ORIGINAL LEARNING. MEAN GROUP SCORES IN TERMS OF TRIALS, ERRORS, AND TIME OF THE NINE EXPERIMENTAL GROUPS (FIRST GENERATION)

Group	No.	Trials			Errors			Time		
		Mean	σ	$\frac{\sigma}{\sqrt{N}}$	Mean	σ	$\frac{\sigma}{\sqrt{N}}$	Mean	σ	$\frac{\sigma}{\sqrt{N}}$
Gc	16	13.6	5.0	1.25	113.4	67.5	16.87	4857	4190	1048
Gx	16	22.4	9.3	2.33	132.9	42.3	10.58	4512	3126	782
Ch	17	27.1	10.6	2.57	154.5	48.1	11.67	6121	3470	842
Xx	15	21.7	8.5	2.20	123.9	53.6	13.84	4005	3110	803
Xc	15	27.4	9.7	2.50	175.9	63.3	16.34	6691	4160	1074
Xh	15	28.9	12.7	3.28	146.2	47.1	12.16	4881	2400	620
Hh	12	53.9	23.8	6.87	258.8	85.7	24.70	10579	6760	1952
Hx	12	47.8	23.9	6.90	272.4	144.7	41.77	9735	11990	3461
Hc	11	60.9	29.8	8.98	358.2	161.6	48.72	14109	6620	1996

of the hot room rats in each group were unable to master the maze in 100 trials tended to draw the average above the median. The opposite tendency was noted in the case of the animals

from the cold room; namely, that the median scores for trials, errors, and time tended to remain above the average scores. In this case the average assumed a lower position than did the median because of several extremely low scores in each

TABLE XII

MEASURES OF ORIGINAL LEARNING. MEAN, MEDIAN AND RANGE FOR TRIALS, ERRORS, AND TIME OF THE NINE EXPERIMENTAL GROUPS (FIRST GENERATION)

	Trials			Errors			Time		
	Mean	Mdn.	Range	Mean	Mdn.	Range	Mean	Mdn.	Range
Cc	13.6	14.5	6 to 22	113.4	107	43 to 322	4857	3627	1128 to 15,153
Cx	22.4	24.5	8 to 39	132.9	145.5	44 to 196	4512	2959.	852 to 12,664
Ch	27.1	26	10 to 47	154.5	143	75 to 257	6121	5911	1193 to 16,126
Xx	21.7	20	7 to 39	123.9	120	60 to 279	4005	3091	1444 to 12,771
Xh	28.9	28	10 to 53	146.2	154	69 to 245	4881	3840	1960 to 10,077
Xc	27.4	25	12 to 46	175.9	152	91 to 313	6691	5126	3313 to 17,399
Hh	53.9	49.5	22 to 99	258.8	269	119 to 397	10579	9836	2452 to 26,970
Hx	47.8	41.5	8 to 100	272.4	241	60 to 570	9735	8106.	1208 to 25,477
Hc	60.9	45	12 to 100	358.2	381	77 to 660	14109	14524	3569 to 33,253

TABLE XIII

RELIABILITY (CRITICAL RATIOS) OF THE DIFFERENCES IN TERMS OF TRIALS,
 ERRORS, AND TIME WHEN EACH OF THE NINE EXPERIMENTAL GROUPS IS
 COMPARED WITH EACH OF THE OTHER EIGHT GROUPS

Group	Trials				Errors				Time			
	Mean	Diff	σ Diff	C.R.	Mean	Diff	σ Diff	C.R.	Mean	Diff	σ Diff	C.R.
Cc	13.6	8.8	2.64	3.33	113.4	19.5	19.9	.98	4857	345	1308	.26
Cx	22.4				132.9				4512			
Cc	13.6	13.5	2.86	4.72	113.4	41.1	20.5	2.01	4857	1264	1344	.94
Ch	27.1				154.5				6121			
Cx	22.4	4.7	3.47	1.35	132.9	21.6	15.7	1.38	4512	1609	1149	1.40
Ch	27.1				154.5				6121			
Xx	21.7	5.7	3.32	1.72	123.9	52.0	21.4	2.43	4005	2686	1341	2.00
Xc	27.4				175.9				6691			
Xx	21.7	7.2	3.94	1.83	123.9	22.3	18.4	1.21	4005	876	1015	.86
Xh	28.9				146.2				4881			
Xh	28.9	1.5	4.12	.36	146.2	29.7	20.4	1.46	4881	1810	1240	1.46
Xc	27.4				175.9				6691			
Hh	53.9	6.1	9.74	.63	258.8	13.6	47.5	.29	10579	844	3974	.21
Hx	47.8				272.4				19735			
Hh	53.9	7.0	11.31	.62	258.8	99.4	54.6	1.82	10579	3530	2792	1.26
Hc	60.9				358.2				14109			

TABLE XIII (Continued)

Group	Trials				Errors				Time			
	Mean	Diff	σ Diff	C.R.	Mean	Diff	σ Diff	C.R.	Mean	Diff	σ Diff	C.R.
Hc	60.9				358.2				14109			
Hx	47.8	13.1	11.32	1.16	272.4	85.8	64.2	1.34	9735	4374	3995	1.09
Cc	13.6	8.1	2.52	3.21	113.4	10.5	21.8	.43	4857	852	1320	.65
Xx	21.7				123.9				4005			
Cc	13.6	40.3	6.98	5.77	113.4	145.4	29.9	4.86	4857	5722	2216	2.58
Hh	53.9				258.8				10579			
Cc	13.6	13.8	2.79	4.95	113.4	62.5	23.5	2.66	4857	1834	1501	1.22
Xc	27.4				175.9				6691			
Cc	13.6	47.3	9.07	5.21	113.4	244.8	51.5	4.75	4857	9252	2254	4.11
Hc	60.9				358.2				14109			
Cc	13.6	15.3	3.51	4.36	113.4	32.8	20.8	1.58	4857	24	1218	.02
Xh	28.9				146.2				4881			
Cc	13.6	34.2	7.01	4.88	113.4	159.0	45.1	3.53	4857	4878	3616	1.35
Hx	47.8				272.4				9735			
Cx	22.4	.7	3.20	.22	132.9	9.0	17.4	.52	4512	507	1121	.45
Xx	21.7				123.9				4005			
Cx	22.4	5.0	3.41	1.47	132.9	43.0	19.5	2.21	4512	2179	1329	1.64
Xc	27.4				175.9				6691			
Cx	22.4	38.5	9.28	4.15	132.9	225.3	49.8	4.52	4512	9597	2144	4.48
Hc	60.9				358.2				14109			

TABLE XIII (Continued)

Group	Trials				Errors				Time			
	Mean	Diff	σ Diff	C.R.	Mean	Diff	σ Diff	C.R.	Mean	Diff	σ Diff	C.R.
Cx	22.4	6.5	4.02	1.62	132.9	13.3	16.1	.83	4512	369	998	.37
Xh	28.9				146.2				4881			
Cx	22.4	25.4	7.28	3.49	132.9	139.5	43.1	3.24	4512	5223	3548	1.47
Hx	47.8				272.4				9735			
Cx	22.4	31.5	7.25	4.34	132.9	125.9	26.9	4.68	4512	6067	2103	2.89
Hh	53.9				258.8				10579			
Ch	27.1	5.4	3.38	1.60	154.5	30.6	18.1	1.69	6121	2116	1164	1.82
Xx	21.7				123.9				4005			
Ch	27.1	.3	3.58	.08	154.5	21.4	20.1	1.07	6121	570	1365	.42
Xc	27.4				175.9				6691			
Ch	27.1	1.8	4.16	.43	154.5	8.3	16.8	.49	6121	1240	1046	1.19
Xh	28.9				146.2				4881			
Ch	27.1	26.8	7.33	3.66	154.5	104.3	27.3	3.82	6121	4458	2126	2.10
Hh	53.9				258.8				10579			
Ch	27.1	33.8	9.35	3.62	154.5	203.7	50.1	4.07	6121	7988	2166	3.69
Hc	60.9				358.2				14109			
Ch	27.1	20.7	7.36	2.81	154.5	117.9	43.4	2.72	6121	3614	3562	1.02
Hx	47.8				272.4				9735			
Xx	21.7	32.2	7.21	4.47	123.9	134.9	28.4	4.75	4005	6574	2111	3.11
Hh	53.9				258.8				10579			

TABLE XIII (Continued)

Group	Trials				Errors				Time			
	Mean	Diff	σ Diff	C.R.	Mean	Diff	σ Diff	C.R.	Mean	Diff	σ Diff	C.R.
Xx	21.7				123.9				4005			
Hc	60.9	39.2	9.25	4.24	358.2	234.3	50.6	4.63	14109	10104	2151	4.70
Xx	21.7				123.9				4005			
Hx	47.8	26.1	7.24	3.61	272.4	148.5	44.0	3.38	9735	5730	3553	1.61
Xc	27.4				175.9				6691			
Hh	53.9	26.5	7.31	3.63	258.8	82.9	29.6	2.80	10579	3888	2228	1.75
Xc	27.4				175.9				6691			
Hc	60.9	33.5	9.32	3.59	358.2	182.3	51.4	3.55	14109	7418	2267	3.27
Xc	27.4				175.9				6691			
Hx	47.8	20.4	7.34	2.78	272.4	96.5	44.9	2.15	9735	3044	3624	.84
Xh	28.9				146.2				4881			
Hh	53.9	25.0	7.61	3.41	258.8	112.6	27.5	4.10	10579	5698	2048	2.78
Xh	28.9				146.2				4881			
Hc	60.9	32.0	9.56	3.35	358.2	212.0	50.2	4.22	14109	9228	2090	4.42
Xh	28.9				146.2				4881			
Hx	47.8	18.9	7.64	2.47	272.4	126.2	43.5	2.90	9735	4854	3516	1.38

TABLE XIV

GROUP DIFFERENCES IN TERMS OF TRIALS RANKED ACCORDING TO
THE SIZE OF THE CRITICAL RATIO*

Rank	Pair	C.R.	Rank	Pair	C.R.	Rank	Pair	C. R.	Rank	Pair	C.R.
1	Cc	5.77	10	Cx	4.15	19	Cc	3.33	28	Cx	1.47
	Hh			Hc			Cx			Xc	
2	Cc	5.21	11	Ch	3.66	20	Cc	3.21	29	Cx	1.35
	Hc			Hh			Xx			Ch	
3	Cc	4.95	12	Xc	3.63	21	Ch	2.81	30	Hx	1.16
	Xc			Hh			Hx			Hc	
4	Cc	4.88	13	Ch	3.62	22	Xc	2.78	31	Hx	.63
	Hx			Hc			Hx			Hh	
5	Cc	4.72	14	Xx	3.61	23	Xh	2.47	32	Hh	.62
	Ch			Hx			Hx			Hc	
6	Xx	4.47	15	Xc	3.59	24	Xx	1.83	33	Ch	.43
	Hh			Hc			Xh			Xh	
7	Cc	4.36	16	Cx	3.49	25	Xx	1.72	34	Xc	.36
	Xh			Hx			Xc			Xh	
8	Cx	4.34	17	Xh	3.41	26	Cx	1.62	35	Xx	.22
	Hh			Hh			Xh			Cx	
9	Xx	4.24	18	Xh	3.35	27	Xx	1.60	36	Ch	.08
	Hc			Hc			Ch			Xc	

*In tables XIV, XV, and XVI the group having the highest average within each pair is given the top position.

of the three cold room groups. The median trial, error, and time scores for the control room rats approximate quite closely the average scores. The range which is also given in Table XII offers additional support in differentiating the groups from one another. Here again the cold room groups had the advantage. The wide range of scores for the hot room rats is especially

TABLE XV

GROUP DIFFERENCES IN TERMS OF ERRORS RANKED ACCORDING TO
THE SIZE OF THE CRITICAL RATIO

Rank	Pair	C.R.	Rank	Pair	C. R.	Rank	Pair	C.R.	Rank	Pair	C.R.
1	Cc	4.86	10	Ch	3.82	19	Xx	2.43	28	Hx	1.34
	Hh			Hh			Xc			Hc	
2	Cc	4.75	11	Xc	3.55	20	Cx	2.21	29	Xx	1.21
	Hc			Hc			Xc			Xh	
3	Xx	4.75	12	Cc	3.53	21	Xc	2.15	30	Ch	1.07
	Hh			Hx			Hx			Xc	
4	Cx	4.68	13	Xx	3.38	22	Cc	2.01	31	Cc	.98
	Hh			Hx			Ch			Cx	
5	Xx	4.63	14	Cx	3.24	23	Hh	1.82	32	Cx	.83
	Hc			Hx			Hc			Xh	
6	Cx	4.52	15	Xh	2.90	24	Xx	1.69	33	Xx	.52
	Hc			Hx			Ch			Cx	
7	Xh	4.22	16	Xc	2.80	25	Cc	1.58	34	Xh	.49
	Hc			Hh			Xh			Ch	
8	Xh	4.10	17	Ch	2.72	26	Xh	1.46	35	Cc	.48
	Hh			Hx			Xc			Xx	
9	Ch	4.07	18	Cc	2.66	27	Cx	1.38	36	Hh	.29
	Hc			Xc			Ch			Hx	

significant. While 53 was the highest number of trials required by any individual from any of the other groups, it can be seen that a number of the rats in each of the groups from the hot room had not learned the maze at the end of 100 trials. The number of rats in each group from the hot room which had not mastered the maze in 100 trials is as follows: Hh, 3; Hx, 2; Hc, 4.

TABLE XVI

GROUP DIFFERENCES IN TERMS OF TIME RANKED ACCORDING TO THE
SIZE OF THE CRITICAL RATIO

Rank	Pair	C.R.	Rank	Pair	C.R.	Rank	Pair	C.R.	Rank	Pair	C.R.
1	Xx	4.70	10	Cc	2.53	19	Cx	1.40	28	Xx	.86
	Hc			Hh			Ch			Xh	
2	Cx	4.48	11	Ch	2.10	20	Xh	1.38	29	Xc	.84
	Hc			Hh			Hx			Hx	
3	Xh	4.42	12	Xx	2.00	21	Cc	1.35	30	Xx	.65
	Hc			Xc			Hx			Cc	
4	Cc	4.11	13	Xx	1.82	22	Hh	1.26	31	Xx	.45
	Hc			Ch			Hc			Cx	
5	Ch	3.69	14	Xc	1.75	23	Cc	1.22	32	Ch	.42
	Hc			Hh			Xc			Xc	
6	Xc	3.27	15	Cx	1.64	24	Xh	1.19	33	Cx	.37
	Hc			Xc			Ch			Xh	
7	Xx	3.11	16	Xx	1.61	25	Hx	1.09	34	Cx	.26
	Hh			Hx			Hc			Cc	
8	Cx	2.89	17	Cx	1.47	26	Ch	1.02	35	Hx	.21
	Hh			Hx			Hx			Hh	
9	Xh	2.78	18	Xh	1.46	27	Cc	.94	36	Cc	.02
	Hh			Xc			Ch			Xh	

In Tables XIV, XV, and XVI, the critical ratios for the 36 group-comparisons in terms of trials, errors, and time, respectively, are arranged from highest to lowest. This makes it possible to see at a glance which group comparisons show the most reliable differences. In Table XIV 20 of the 36 critical ratios are above 3.00 and 27 are above 1.50; in Table XV 14 of the 36 critical ratios are above 3.00 and 25

TABLE XVII

MEASURES OF ORIGINAL LEARNING WHEN THE NINE GROUPS ARE COMBINED ACCORDING TO THEIR RESPECTIVE ROOMS (FIRST GENERATION)

Group	No.	Trials			Errors			Time		
		Mean	σ	$\frac{\sigma}{\sqrt{N}}$	Mean	σ	$\frac{\sigma}{\sqrt{N}}$	Mean	σ	$\frac{\sigma}{\sqrt{N}}$
C	49	21.0	10.4	1.49	133	57.4	8.20	5163	3761	537
X	45	26.0	11.2	1.67	149	59.1	8.81	5192	3437	520
H	35	54.2	26.4	4.46	297	140.6	23.77	11478	7291	1232

are above 1.50; in Table XVI, 7 of the 36 critical ratios are above 3.00, but 16 are above 1.50; thus it can be said that there are more reliable differences when one compares the various groups in terms of average number of trials. In Table XIV the highest critical ratio is 5.77 and the lowest is .08. The most reliable difference in terms of trials is that found between the Cc and the Hh groups; the least reliable difference is that found between the Ch and Xc groups, as one would expect.

In general, Tables XIV, XV, and XVI, show that the most reliable differences are those between the groups from the cold and hot rooms. The differences between the groups from the control and hot rooms are also reliable, but, in general are less so than the differences between the cold and hot room groups.

While we are concerned with differences such as have just been presented, a more striking picture is obtained

TABLE XVIII

RELIABILITY(CRITICAL RATIOS)OF THE DIFFERENCES IN TERMS OF TRIALS, ERRORS,
AND TIME WHEN EACH OF THE THREE COMBINED GROUPS IS COMPARED
WITH EACH OF THE OTHER TWO GROUPS(FIRST GENERATION)

Group	Trials				Errors				Time			
	Mean	Diff	σ Diff	C.R.	Mean	Diff	σ Diff	C.R.	Mean	Diff	σ Diff	C.R.
C	21.0	6.0	2.23	2.69	133.0	15.7	12.03	1.31	5163	29	747.5	.039
X	26.0				148.7				5192			
C	21.0	33.2	4.71	7.05	133.0	163.5	25.14	6.50	5163	6315	1344	4.70
H	54.2				296.5				11478			
X	26.0	28.2	4.76	5.92	148.7	147.8	25.34	5.83	5192	6286	1337	4.70
H	54.2				296.5				11478			

from learning curves (see appendix). The learning curves were plotted from composite data and are to be used only as rough measures in making group comparisons. Smoothed curves would probably add little toward a more complete description of the course of learning as found in the various groups. Since these curves are composite curves, it is important to point out that the latter portion of any one curve is not representative of the performance of the entire group. This is especially true in the case of the curves for the hot room groups, in which case the latter portions of the curves represent only a few individuals from the entire group. In spite of the limitations of this type of curve, its use does serve a purpose in the description of gross differences.

When one examines the learning curves (appendix), it can be observed, in the first place, that the general differences which were brought out through the use of tables are described more fully by learning curves. Besides this, the curves point toward other differences. For example, it can be observed that all groups were quite similar in their performance during the first few initial trials in the maze, a similarity that disappeared during subsequent trials. In general it can be said that animals from the cold room eliminated errors faster and decreased more rapidly the amount of time required for each trial, and reached the point of complete learning sooner than did those animals from the

other rooms. Regardless of which group from the hot room one considers, it can be noted that after this group reached a certain degree of proficiency (in general after 10 to 15 trials) the elimination of errors and the decrease in amount of time per trial came about slowly. This raises the question as to the real reason for the tendency on the part of the hot room rats to make an average of four or five errors per trial, a problem that will be discussed later.

The learning curves demonstrate further the fact that the temperature of the room in which the rat learns the maze is an important factor in maze performance. For example, that group of curves which represents the course of learning of the Cc, Cx, and Ch groups makes it clear that the Cc group not only eliminated errors and decreased the amount of time required per trial more rapidly, but also proceeded with more regularity and came to complete learning sooner than was the case in the Cx and Ch groups. This tendency for the rats that learned the maze in their home room to do better is shown in the case of those curves which describe the progress of learning in groups, Xx, Xc, and Xh. This characteristic appears to be present in the Hh, Hx, and Hc groups as well. A further discussion of these learning curves will be found in the appendix.

From the results it appears evident that both the temperature in which the animal was raised and the temperature of the room in which learning takes place are important factors in learning. Combining the data from the three groups for

each individual room gives the measures found in Table XVII. The cold room rats were superior to the other two groups. In comparing the data from the three combined groups, one can see that there is a significant difference relative to all the criteria of learning with one possible exception, namely, the difference in time between the animals from the cold room and those from the control room. Table XVIII shows the statistical reliability of the differences in the form of critical ratios. In general these measures are well above the level of statistical requirements. Therefore, animals raised in the cool, stimulating temperature of the cold room, regardless of the temperature of the room in which they learned the maze, were superior in maze performance to the other two groups which were reared under less stimulating temperature conditions.

As was pointed out in Chapter III, the entire experiment was repeated with animals from the second generation. Similar controls were used and identical experimental conditions were maintained. In Tables XIX, XX, XXI, and XXII are the data for the maze performance of the second generation. Since the differences between the first and second generation were relatively small and unreliable, each table will not be considered separately and in detail. There are, however, several differences which are apparently quite significant. From Table XXIII it can be seen that the highest critical ratios are found between the Ch groups of the first and second generation. The size of these measures would suggest quite strongly that the second generation Ch group was affected more by the temp-

TABLE XIX

MEASURES OF ORIGINAL LEARNING: MEAN GROUP SCORES IN TERMS OF TRIALS, ERRORS, AND TIME OF THE NINE EXPERIMENTAL GROUPS (SECOND GENERATION)

Group	No.	Trials			Errors			Time		
		Mean	σ	$\frac{\sigma}{\sqrt{N}}$	Mean	σ	$\frac{\sigma}{\sqrt{N}}$	Mean	σ	$\frac{\sigma}{\sqrt{N}}$
Cc	14	14.7	6.5	1.74	101.6	35.4	9.46	4718	2665	712
Cx	14	18.3	9.8	2.62	127.1	56.5	15.10	5823	6201	1657
Ch	15	34.3	18.1	4.67	175.0	61.6	15.91	10049	5575	1440
Xx	15	24.9	10.3	2.66	123.5	52.1	13.45	3425	1525	394
Xc	15	30.7	17.4	4.49	187.6	79.8	20.60	7629	3426	885
Xh	16	31.6	18.4	4.60	157.3	80.9	20.23	5970	4753	1188
Hh	12	42.8	21.7	6.26	251.1	69.2	19.98	8936	6408	1850
Hx	12	49.0	22.9	6.61	235.0	87.1	25.14	8322	3483	1006
Hc	12	51.3	21.6	6.24	356.3	152.5	44.02	16724	7166	2069

erature in the hot room than was the Ch group of the first generation. This might mean that animals which have adapted to cool stimulating temperatures through at least one generation are affected more upon being forced to learn a maze in conditions of depressive heat than are those which have made adaptation to cold temperatures after first spending the early weeks of their life in warmer temperatures.

Another difference which might be significant is that of the tendency of the second generation animals from the hot room to reach a slightly higher level of performance than was

TABLE XX

MEASURES OF ORIGINAL LEARNING: MEAN, MEDIAN, AND RANGE
FOR TRIALS, ERRORS, AND TIME OF THE NINE EXPERIMENTAL
GROUPS (SECOND GENERATION)

Group	Trials			Errors			Time		
	Mean	Mdn.	Range	Mean	Mdn.	Range	Mean	Mdn.	Range
Cc	14.7	15.5	6 to 27	101.6	108.5	39 to 154	4718	3748	1676 to 10039
Cx	18.3	15.5	6 to 38	127.1	133.0	39 to 212	5823	2707	888 to 12476
Ch	34.3	28.0	7 to 79	175.0	157.0	105 to 328	10049	10045	2735 to 19479
Xx	24.9	24.0	11 to 47	123.5	115.0	51 to 282	3425	2954	1774 to 7304
Xh	31.6	32.5	6 to 87	157.3	132.0	60 to 381	5970	4266	910 to 18729
Xc	30.7	27.0	14 to 71	187.6	174.0	85 to 325	7629	6072	2864 to 19645
Hh	42.8	38.0	22 to 100	215.1	194.0	114 to 372	8936	7363	1169 to 20729
Hx	49.0	45.5	13 to 100	235.0	232.0	84 to 391	8322	9484	2681 to 13497
Hc	51.3	46.0	20 to 92	356.3	285.5	119 to 624	16724	16469	2164 to 29640

the case in the first generation. A physiological adaptation might have been the cause of this. That is, the physiological adaptation which obviously took place in this generation could easily have been responsible for an added efficiency in behavior. Yet, before asserting this difference to be real and

TABLE XXI

MEASURES OF ORIGINAL LEARNING WHEN THE NINE GROUPS ARE COMBINED ACCORDING TO THEIR RESPECTIVE ROOMS (SECOND GENERATION)

Group	No.	Trials			Errors			Time		
		Mean	σ	$\frac{\sigma}{\sqrt{N}}$	Mean	σ	$\frac{\sigma}{\sqrt{N}}$	Mean	σ	$\frac{\sigma}{\sqrt{N}}$
C	43	22.4	15.3	2.33	135	60.9	9.29	6863	5523	842
X	46	29.1	16.1	2.37	156	93.7	15.62	5675	4452	656
H	36	47.7	22.4	3.73	269	117.8	19.63	11327	7543	1224

reliable, one must consider further several aspects of the behavior of the second generation.

Within the limits of permissible statistical variability, the averages for the second generation were comparable to those of the first. The data from the performance of the second generation give added support to the conclusions which were drawn from the performance of the first generation. Since the performances of the two generations were so similar, a repeated discussion concerning the differences existent among the various groups would be pointless.

The Retention Experiments

Especially in the case of the groups from the hot room, not all the rats which learned the maze originally could be made to relearn it thirty days later. As was described in Chapter III, after five 15 minute periods during which the animal failed to reach the food, he was removed from the

TABLE XXII

RELIABILITY (CRITICAL RATIOS) OF THE DIFFERENCES IN TERMS OF TRIALS, ERRORS,
AND TIME WHEN EACH OF THE THREE COMBINED GROUPS IS COMPARED WITH
EACH OF THE OTHER TWO GROUPS (SECOND GENERATION)

Group	Trials				Errors				Time			
	Mean	Diff	σ Diff	C.R.	Mean	Diff	σ Diff	C.R.	Mean	Diff	σ Diff	C.R.
C	22.4				135				6863			
X	29.1	6.7	3.33	2.01	156	21	18.17	1.16	5675	1188	1067	1.11
C	22.4				135				6863			
H	47.7	25.3	4.40	5.75	269	134	21.72	6.17	11327	4464	1486	3.00
X	29.1				156				5675			
H	47.7	18.6	4.42	4.21	269	113	25.08	4.52	11327	5652	1388	4.07

TABLE XXIII

RELIABILITY (CRITICAL RATIOS) OF THE DIFFERENCES BETWEEN THE SCORES OF THE FIRST AND SECOND GENERATION IN TERMS OF TRIALS, ERRORS, AND TIME

Group	Trials				Errors				Time			
	Mean	Diff	σ Diff	C.R.	Mean	Diff	σ Diff	C.R.	Mean	Diff	σ Diff	C.R.
Cc1	13.6				113.4				4857			
Cc2	14.7	1.1	2.14	.51	101.6	11.8	19.34	.61	4718	139	1267	.11
Cx1	22.4				132.9				4512			
Cx2	18.3	4.1	3.50	1.17	127.1	5.8	18.43	.32	5823	1311	1832	.72
Ch1	27.1				154.5				6121			
Ch2	34.3	7.2	5.33	1.35	175.0	20.5	19.72	1.04	10049	3928	1667	2.36
Xx1	21.7				123.9				4005			
Xx2	24.9	3.2	3.45	.93	123.5	.4	19.30	.02	3425	580	895	.65
Xc1	27.4				175.9				6691			
Xc2	30.7	3.3	5.14	.64	187.6	11.7	26.30	.45	7629	938	1391	.67
Xh1	28.9				146.2				4881			
Xh2	31.6	2.7	5.65	.48	157.3	11.1	23.60	.47	5970	1089	1340	.81
Hh1	53.9				258.8				10579			
Hh2	42.8	11.1	9.30	1.19	215.1	43.7	31.80	1.37	8936	1643	2689	.61
Hx1	47.8				272.4				9735			
Hx2	49.0	1.2	9.55	.13	235.0	37.4	48.75	.77	8322	1413	3604	.39
Hc1	60.9				358.2				14109			
Hc2	51.3	9.6	10.93	.88	356.3	1.9	65.66	.03	16724	2615	2875	.91

experiment. A description of this "stubborn" behavior which appeared in connection with the relearning situation will be found in the latter part of this chapter. It is important that this form of behavior be mentioned here in order to qualify some of the data which appear in the tables. The following is a brief statement of the number of rats in each group which failed in the relearning situation: Cc, 0; Cx, 0; Ch, 0; Xx, 0; Xc, 1; Xh, 0; Hh, 2; Hc, 5; Hx, 2. Not a single rat from the cold room failed to relearn, and only one from the control room; whereas nine from the various groups in the hot room refused to relearn the maze.

As shown in Table XXIV, the hot room rats required more than twice as many trials, made almost three times as many errors, and took more than twice as much time in relearning the maze than did rats from the cold room. In terms of absolute differences, the control room rats appear to have been slightly inferior to the cold room rats, this, in general, is not a significantly reliable difference.

The percentages of saving in each group (Table XXV) show differences that are relatively insignificant. The slight differences which do exist are in favor of the control room animals. It may be suggested that the percentage saving by the hot room animals would have been smaller if all the animals that had originally learned the maze had also relearned it. Of course, another reason for the relatively high level of this percentage lies in the fact that the original scores, in terms of which the saving was made, were

TABLE XXIV

MEASURES OF RELEARNING: MEAN GROUP SCORES OF THE NINE EXPERIMENTAL GROUPS IN TERMS OF TRIALS, ERRORS, AND TIME (FIRST GENERATION)

Group	No.	Trials			Errors			Time		
		Mean	σ	$\frac{\sigma}{\sqrt{N}}$	Mean	σ	$\frac{\sigma}{\sqrt{N}}$	Mean	σ	$\frac{\sigma}{\sqrt{N}}$
Cc	16	8.9	6.6	1.65	19.9	16.2	4.05	786	939	235.
Cx	16	9.7	8.1	2.03	33.8	27.1	6.78	1585	1785	446
Ch	17	12.6	10.4	2.52	42.3	45.4	11.01	2591	3161	767
Xx	15	9.1	5.8	1.50	16.6	14.5	3.74	525	425	110
Xc	14	9.1	5.3	1.42	35.4	24.2	6.47	1735	1669	446
Xh	15	14.3	7.3	1.89	35.3	35.3	9.11	2113	2091	540
Hh	10	19.6	12.7	4.02	72.3	45.1	14.26	3897	3135	992
Hx	10	22.6	19.3	6.10	80.2	79.8	25.24	3320	3120	987
Hc	6	25.5	11.9	4.86	102.8	82.5	33.69	3705	3837	1567

high in relation to the original scores for the rats from the control and cold rooms.

Table XXIV illustrates the differences in retention as found among the various groups. As in the case of original learning, the temperature of the room in which the relearning takes place exerts an important influence on the amount of learning, the variability as indicated by the size of the sigma, the number of trials and errors, and, the time required. The sigmas for the groups from the hot room are much larger than they are for the groups from either of the other two rooms.

TABLE XXV

PERCENT SAVING IN RELEARNING (FIRST GENERATION)

Group	Trials				Errors				Time				Mean %
	Orig. learn.	Re-learn.	Sav- ing	% Sav- ing	Orig. learn.	Re- learn.	Sav- ing	% Sav- ing	Orig. learn.	Re- learn.	Sav- ing	% Sav- ing	
					Cold Room								
Cc	13.6	8.9	4.7	34.6	113.4	19.9	93.5	82.5	4857	786	4071	83.8	67.0
Cx	22.4	9.7	12.7	56.7	132.9	33.8	99.1	74.6	4512	1585	2927	64.9	65.4
Ch	27.1	12.6	14.5	53.5	154.5	42.3	112.2	72.6	6121	2591	3530	57.7	61.3
Mean	21.0	10.4	10.6	48.3	133.6	32.0	101.6	76.6	5163	1654	3509	68.8	64.6
					Control Room								
Xx	21.7	9.1	12.6	58.1	123.9	16.6	107.3	86.6	4005	525	3480	86.9	77.2
Xc	27.4	9.1	18.3	66.8	175.9	35.4	140.5	79.9	6691	1735	4956	74.1	73.6
Xh	28.9	14.3	14.6	50.5	146.2	35.3	110.9	75.9	4881	2113	2768	56.7	61.0
Mean	26.0	10.8	15.2	58.5	148.7	29.1	119.6	80.8	5192	1458	3735	72.6	70.6
					Hot Room								
Hh	53.9	19.6	34.3	63.6	258.8	72.3	186.5	72.1	10579	3897	6682	63.2	66.3
Hx	47.8	22.6	25.2	52.7	272.5	80.2	192.2	70.5	9735	3320	6415	65.9	63.0
Hc	60.9	25.5	35.4	58.1	358.2	102.8	255.4	71.3	14109	3705	10404	73.7	67.7
Mean	54.2	22.6	31.6	58.1	296.5	85.1	211.4	71.3	11473	3641	7834	67.6	65.7

TABLE XXVI

MEASURES OF RELEARNING: MEAN GROUP SCORES OF THE NINE EXPERIMENTAL GROUPS IN TERMS OF TRIALS, ERRORS, AND TIME (SECOND GENERATION)

Group	No.	Trials			Errors			Time		
		Mean	σ	$\frac{\sigma}{\sqrt{N}}$	Mean	σ	$\frac{\sigma}{\sqrt{N}}$	Mean	σ	$\frac{\sigma}{\sqrt{N}}$
Cc	12	4.4	2.6	.74	12.7	11.1	3.20	521	612	177
Cx	12	14.5	6.0	1.73	38.6	20.3	5.86	1978	1343	389
Ch	13	7.9	6.0	1.66	24.9	27.1	7.52	1407	1872	519
Xx	15	7.7	4.3	1.11	17.8	24.4	6.30	696	1130	292
Xc	13	11.8	9.2	2.55	42.4	39.6	10.98	1480	1196	332
Xh	15	7.0	6.1	1.58	19.4	28.1	7.26	783	1261	326
Hh	9	17.7	22.5	7.50	55.2	93.2	31.08	2120	3880	1293
Hx	10	24.2	17.3	5.50	68.1	56.2	17.78	2608	2969	939
Hc	8	16.8	10.2	3.64	46.5	28.3	9.99	3362	3519	1244

The measures which represent the amount of retention in the second generation (Table XXVI) indicate no particular difference from the amount of retention in the first generation. In general, however, all the groups in the second generation show some superiority over the corresponding groups in the first generation. This again may be the result of a temperature adaptation. Results obtained from the second generation thus give added weight to the conclusions drawn from the first generation.

TABLE XXVII
PERCENT SAVING IN RELEARNING (SECOND GENERATION)

Group	Trials				Errors				Time				
	Orig. learn.	Re- learn.	Sav- ing	% Sav- ing	Orig. learn.	Re- learn.	Sav- ing	% Sav- ing	Orig. learn.	Re- learn.	Sav- ing	% Sav- ing	Mean %
					Cold Room								
Cc	14.7	4.4	10.3	70.1	101.6	12.7	88.9	87.5	4718	521	4197	89.0	82.2
Cx	18.3	14.5	3.8	20.8	127.1	38.6	88.5	69.6	5823	1978	3845	66.0	52.1
Ch	34.3	7.9	26.4	77.0	175.0	24.9	150.1	85.8	10049	1407	8642	86.0	82.9
Mean	22.4	8.9	13.5	56.0	134.6	25.4	109.5	81.0	5530	1302	5561	80.3	72.4
					Control Room								
Xx	24.9	7.7	17.2	69.1	123.5	17.8	105.7	85.6	3425	696	2729	79.7	78.1
Xc	30.7	11.8	18.9	61.6	187.6	42.4	145.2	77.4	7629	1480	6149	80.6	73.2
Xh	31.6	7.0	24.6	77.9	157.3	19.4	137.9	87.7	5970	783	5187	86.9	84.2
Mean	29.1	8.8	20.2	69.5	156.1	26.5	129.6	83.6	5675	986	4688	82.4	78.5
					Hot Room								
Hh	42.8	17.7	25.1	58.6	215.1	55.2	159.9	74.3	8936	2120	6816	76.3	69.7
Hx	49.0	24.2	24.8	50.6	235.0	68.1	166.9	71.0	8322	2608	5714	68.7	63.4
Hc	51.3	16.8	34.5	67.3	356.3	46.5	309.8	86.9	16724	3362	13362	79.9	78.0
Mean	47.7	19.6	28.1	58.8	268.8	56.6	212.2	77.4	11327	2697	8631	75.0	70.4

Qualitative Behavioral Differences

Out of some 500 rats from the various rooms with which the experimenter worked there were no two rats which behaved in an identical manner; furthermore, no one of the nine experimental groups appeared to surpass another in individual differences. But between the groups, important qualitative differences showed up which could not be quantified. A well controlled study of the qualitative differences would make a complete study in itself. These differences demand well controlled study, and are worthy of the interest of future investigators. In fact, these differences may prove to be as important as the quantitative data, if not more so, in understanding the effect of temperature on behavior. Since few differences were noted between the respective groups from the first and second generation, the two generations will be treated together.

First, consider the maze behavior of the rats from the hot room. In all three groups, Hh, Hc, and Hx, many of the subjects behaved very peculiarly. Chief among these peculiarities was a "blind dashing back and forth" in some one alley of the maze. While on many of these "mad excursions" the rat would crash into the end of a blind alley. The behavior pattern also exhibited many characteristics of playfulness, jerky and spasmodic movements, inattention, and indecision. Frequently a rat would pause suddenly and then sit in a rigid motionless state. After indulging in this sort of behavior for an unpredictable period of time, the rat would suddenly

(as though it "remembered that there was food to be had in the food box") "strike out" for the food box. After it had once started in the direction of the food box, it would continue at such speed that in turning the corners of the maze, the slapping of his tail against the side of the door-way would serve to announce his passage from one alley to another. These behavior patterns bear some descriptive resemblance to those which Maier (42) found in his "neurotic" animals. In our experiments the behavior appeared, usually after the rats had reached a certain level of proficiency in the maze (after about 15 to 20 trials).

Not all the rats from the hot room showed this form of behavior; however, roughly speaking, about one-third behaved in this fashion--some to a greater extent than others. This behavior showed up in all the groups from the hot room, but there was a tendency for it to be more characteristic of the Hx group.

During the first several days that the rats from the hot room were given maze trials in the cold room, an interesting reaction to the cold was noted. The rat would at first move about rather quickly, stopping frequently to groom and to lick those parts of its body that were relatively unprotected from the cold. This, in fact, partly accounts for the relatively high time score of the Hc group. Much of the time, especially during the earlier stages of training, was spent in scratching, licking, and going through the general process of grooming; however relatively rapid adaptation occurred

and after 15 to 20 trials the rat appeared to be less affected by the change in temperature.

As was pointed out in previous portions of this chapter, on the whole, the rats from the hot room persisted in making several errors on each trial even after the animal apparently "knew the maze". This, of course, was not the case for animals from the other two rooms. This form of behavior is quite interesting and significant. The question as to whether or not the quantitative differences which were exhibited by the various groups represented a difference in level of intelligence will be discussed in Chapter V.

Rats from groups Hh, Hc, and Hx frequently made an errorless run only to be followed by a run with 5 to 20 errors. The maze behavior of the animals from these groups was exceedingly erratic; it was quite impossible to predict the time and error scores for future runs on the basis of the animal's immediately past record. It was very often the case that animals from these groups would make two errorless runs (three errorless runs was the criterion of learning) only to follow with a very imperfect run. This type of behavior was responsible, in the main, for the relatively large number of trials required for learning by the hot room subjects. Many subjects from this group remained unstable and unpredictable throughout the entire course of 100 trials.

The general maze behavior of the groups from the cold and control room requires little descriptive elaboration. The Cc group was, by far, the most interesting and the easiest

group to run. These rats, as a rule, were "most intent on mastering the situation". They were less easily disturbed and were, after the first several trials, definitely oriented in relation to the maze situation. In this group the elimination of errors came about rapidly and complete learning (three consecutive errorless runs) was reached very quickly. In general the Cx group appeared to be somewhat disturbed by the change in temperature. This probably accounts, to a large extent, for the relatively poorer performance of this group over the Cc group. It is not surprising to note that the Ch group was affected to a considerable extent by the high temperature of the hot room. Upon being transferred to this room for the initial trials in the maze, the subjects not infrequently, after exploring the maze, lay down, stretched out, and went to sleep. After the animals had oriented themselves to the situation they were affected to a relatively small extent by the high temperature. Most of the "mal-behavior" exhibited by animals from this group was in the form of going to sleep.

Group Xx was almost as stable as group Cc. The Xc group was affected by the temperatures of the cold room in a fashion which differed only in extent from the Hc group. During the initial trials in the maze, the animals from the Xc group utilized a considerable amount of time in scratching and grooming. The members of group Xh, in general, reacted to the high temperature too. In many cases this reaction was not particularly marked. But the scores of the Xh group were con-

siderably higher than those for the Xx group.

During the initial stages in maze training, some of the rats were removed from the experiment. This was done after 5 incomplete runs were made. (An incomplete run was defined as one in which the animal failed to reach the food in 30 minutes.) It is interesting to note the relative number of subjects from each group which were removed from the experiment. The data are as follows: Cc, 0; Cx, 0; Ch, 2; Xx, 0; Xh, 2; Xc, 4; Hh, 3; Hx, 4; Hc, 9. The significance of this data needs no further discussion.

Significant also is the fact, as discussed previously, that in the relearning situation so many of the subjects from the hot room failed. In this case the animals would move about very little, usually not beyond the first alley of the maze. Even after they were taken from the maze and placed in the food box to eat and started again on another trial they would refuse to move and would continue to show no interest in the maze situation.

Summary of Results

The growth of white rats in temperatures of 90°, 75-85°, and 55°, respectively, has confirmed the observations previously made by other investigators on the dependence of organic differentiation upon the ease with which body heat is lost. In the stimulating coolness of the cold room rats grew the most rapidly as shown by growth curves; they matured earlier, and gave birth to litters of larger, healthier young. In

the less stimulating conditions of the hot room, growth and maturity were delayed; conceptions took place later; the young were small; and many of each litter died shortly after birth. The hot room rats were of smaller adult size. The adult rats in the hot room had an average tail length fully one centimeter longer than those in the cold room. The general activity level of the animals in the hot room might be compared to those characteristics commonly ascribed to people living in the tropics. They were listless, lazy, sluggish, and quite irritable, and unstable, while the animals living in the more invigorating conditions of the cold room were more active, docile, attentive, and easily handled.

With reference to maze running it can be said that the cold rats had a distinct advantage. In general, the subjects from the cold room, according to the three criteria of learning, were from two to three times more efficient in maze learning than the rats from the hot room. The Cc group required an average of 13.6 trials, 113.4 errors, and 4,857 seconds to learn the maze; whereas the Hh group required an average of 53.9 trials, 258.8 errors and 10,579 seconds. The Xx group appeared about mid-way between the two extreme groups. This group required 21.7 trials, 123.9 errors, and 4,005 seconds to learn the maze.

In maze running the temperature level of the room in which the rat learns the maze, as well as the temperature of the room in which he was raised, is an important influencing factor. The Ch group required more trials and time, and made

more errors than did the Cc group; likewise, when learning the maze outside their home room the control rats were at a disadvantage in terms of trials, errors, and time. The rats from the hot room also showed this difference, but to a lesser extent. These animals required an average of fifty to sixty trials, regardless of the room in which they were run. It was found by grouping all the animals from one room together that the cold room rats were superior to the rats from the other rooms.

Relative to retention there appears to have been no significant difference in terms of percentage saving; however the hot room rats required several times as many trials to relearn the maze, but in terms of percentage saving their performance was comparable to that of the other groups.

Significant qualitative differences in maze behavior were noted. Many of the hot room rats, regardless of the room in which they were run, developed a peculiar type of maze behavior. Briefly, it consisted of a dashing back and forth in the alleys of the maze along with very sudden halts in locomotion.

CHAPTER V

INTERPRETATION AND CONCLUSIONS

The purpose of the following discussion is not that of giving final answers, but, on the contrary, to point out the direction, if possible, which seems most promising for a solution of the problem. This Chapter will also present new problems, and will make suggestions for further research. It is hoped that other investigators will become interested and will continue research in this field. The problems which the present program of research has opened are pregnant with possibilities.

This study demonstrates the interdependence of the organism and its climatic environment relative to the organism's physiological, morphological, and behavioral characteristics. The results show clearly that if the nature of the organism is to be adequately understood, one must consider the complete biological unit--the organism functioning in an environment.

The findings of the present study are of special interest in relation to the effect of climate on the character and productiveness of a people. The general activity level of the hot room rats seemed clearly to be comparable to the listless, sluggish, inattentive, and lazy characteristics of races living in the heat of the tropics. On the other hand the general behavioral characteristics of the cold room animals appeared comparable to the higher productive level of peoples living in

regions of climatic optimum. Studies conducted by other investigators, such as Wheeler, Huntington, Petersen, and Mills, are herewith given added meaning, but a detailed discussion of the bearing of this study on their findings is beyond the scope of this project. We are interested in facing the immediate problems raised by the data of Chapter IV.

Let us consider first the significance of the physiological data. Here the influence of temperature on growth and development is clearly demonstrated. On being submitted to various temperature conditions, the rat displays remarkable adaption. In this adaptive process, it not only controls and regulates the relative growth rate of the various body structures, but also mediates a general adjustment through a control over actual body size and general level of physiological functions. As was suggested in Chapter IV, this regulation illustrates an "economy principle"; that is, the organism which is living under conditions of depressing heat regulates and adjusts its body shape and size in such a manner as to maintain the most efficient channels through which body heat may be lost. On the other hand, the organism which is living in cool, stimulating conditions, controls its body shape and size in a fashion most conducive to the conservation of body heat. The long, slender body, long tail, long legs, and larger ears of the animals from the hot room apparently serve to facilitate body heat loss. On the other hand, the short, spherical body, short tail, smaller ears, and short legs of the animals from the cold room serve to preserve body heat.

Since metabolism is a fundamental and universal characteristic of all living tissue, it is not illogical to expect variations in the "vital status" of an organism when conditions which affect the metabolic level are varied. Heat is one of the important by-products of metabolism, and this heat must be disposed of if adequate metabolism is to be maintained. High temperatures make this disposal difficult; cool temperatures facilitate it.

The physiologist is quite aware of the fact that anatomical and functional differentiation is dependent on the metabolic pattern of the organism. He understands also that the organism exhibits metabolic gradients which determine the speed as well as the extent of differentiation in the various body structures. One is safe in anticipating a shift in the metabolic gradients when conditions which are fundamental to metabolic status are changed. This, of course, results not only in variations in the rapidity and extent of growth of the various body regions, but also results in differences of speed and extent of body growth in general. For example, it is quite reasonable to expect an organism with a higher metabolic rate, within certain limits, of course, to develop more quickly and to reach a larger adult size than one with a lower metabolic level. This was seemingly the case with our experimental animals. Studies reported in Chapter II point toward a lower metabolic level in animals living in higher temperatures. If we accept the data from these studies, it may be assumed that our hot room animals maintained a

lower level of metabolism than did those from either the cold or the control room; thus we would expect the hot room animals not only to be smaller, but also to be characterized by the previously mentioned morphological characteristics; furthermore, because of the lower metabolic or energy level, we have adequate reason for assuming that the hot room animals were unable to reach as high a level of physiological and neurological differentiation as did the animals from the other two rooms.

The organism, as an energy system, is concerned fundamentally with maintaining those conditions which are most conducive to the utilization in the most efficient manner of all of its available energy. More than this, the organism seemingly structures itself in such a way that the maximum amount of energy is made available. It can be suggested, therefore, that the rats from the cold room not only were more efficient in utilizing available energy, but also were in a condition, physiological and environmental, where actually more energy was available. Just what the relationship is between the ability to utilize available energy and the various morphological characteristics of the organism is an unsolved problem, mainly for the biophysicist.

Within the limits of this experiment, adaptation to climatic conditions appears to be accumulative from one generation to another. The second generation hot room rats exhibited physiological and morphological characteristics which were exaggerated as compared with the first generation;

likewise the second generation cold room animals showed a higher level of adaptation than did those from the first generation. This might indicate that the biophysics and the biochemistry of the parental germ plasm may be affected by the temperature level in which the parents live. The fact that, at birth, the young born in the high temperature of the hot room were of smaller individual size leads one to suppose further that the temperature of the room in which the pregnant mother lives has a definite influence on the rate of growth of the embryo. Przibram suspected this, and presented preliminary evidence in this direction.

The findings of this study also confirm observations made by Mills and Huntington in regard to the effect of temperature on sexual function. The data of the present study derive their significance, in relation to human problems, through their inferential value; that is, through the inferences which can be made relative to the human being. The large difference in sex ratios which was found in comparing the relative number of males and females born in each room is quite significant; however speculations regarding the cause of this difference are beyond the scope of the present report. That is a problem for the geneticist.

Maze Behavior

The real causes of differences in behavior are numerous and are deeply imbedded in a pattern of complex variables. Moreover the immediate cause for behavior differences must

be looked for in terms of a causal pattern rather than in individual and isolated conditions. Differences in behavior are associated with variables such as extent of neurological differentiation, age level, metabolic rate, dietary constituents, hereditary factors, pathological conditions, and climatic conditions; however no single one of these variables can be pointed to as the sole cause of any one form of behavior. Apparently the best one can do is to vary these conditions systematically and to make observations to see which pattern appears to be most closely related to a particular form of behavior. In discussing behavior differences as found in the present study, we are aware of the fact that temperature is by no means the only factor involved. In the first place, it is impossible to measure the isolated effect of temperature, as such, on behavior because there are numerous intervening variables involved which defy separation and analysis. The complexity of the task of isolating and studying the numerous intervening variables presents detailed and difficult problems, the answers to which cannot be given on the basis of experimental data which are available at the present time. Of course, in the present study we have not been interested in isolating these intervening variables; instead, we have been interested in paving the way for more refined and elaborate investigations. This study demonstrates gross differences which appear concomitantly with temperature variations.

A project of this sort would not be complete until the

nature of the relationship between variations in general metabolic level and behavior were known. Furthermore, as the reader has no doubt concluded for himself, the data presented in this thesis do not isolate the "insightful" aspects of maze learning under differential temperature conditions from the "motivational" aspects, nor was it our purpose to make such an attempt. Investigations that might appropriately follow this one could be designed to answer the following questions. (1) Are the hot room rats less motivated as well as less intelligent? (2) Are they as intelligent as the cold room rats but less motivated? These questions raise the further problem, is a more intelligent animal also more motivated for the same reason that it is more intelligent? Since the effect of temperature on behavior is mediated, to some extent at least, through the two inter-dependent variables, it is important that this fact be recognized and considered in our discussion.

Although no exact quantitative data are available, it can be reported that the animals in the hot room ate less than the animals in either of the other two rooms. Since food was used as the incentive in the maze and since all groups were deprived of food for the same length of time (24 hours), the following question naturally arises. Were the hot room animals as strongly "motivated" as the cold room animals? This question of differences in motivation is given added importance when one considers the qualitative maze behavior differences. For

example, as was pointed out in Chapter IV, many of the hot room animals exhibited "careless," "carefree," "erratic," and "playful" forms of maze behavior. Some of the animals exhibited behavior similar to that which Maier (41) labels "inattention." The tendency on the part of the hot room animals to persist in making several errors per trial, even after they apparently "knew" the maze, may also suggest lack of motivation. On the other hand, the fact that the cold room rats when learning the maze outside their home room were inferior to those who learned the maze in the cold room strongly suggests that the motivational factor, as such, could not have been caused alone by "food need." But in this case, as in all others, we are unable to differentiate between the direct effect of the temperature and the indirect effect through the "drive" for food. Note also that when in the immediate presence of food, the hot room rats gave no real indication of not being "hungry"; they apparently ate just as readily and with as much zeal as did the animals from the other two rooms. In fact, on several occasions the hot room rats, when hungry, competed for food more vigorously than did the cold room rats.

A detailed discussion of the concept of motivation is beyond the scope of this thesis, but since our results raise the issue a brief discussion of motivation will not be out of order.

In experimental psychology the term motivation has been used most frequently to describe the status of certain physiological or internal drives in relation to appropriate incentives. In this usage, motivation is considered as a dependent or intervening variable. In the case of hunger the variable is controlled by a manipulation of the food schedule; in the case of the sex drive, it is controlled by sexual deprivation. An experimental attack on this problem is by no means an easy undertaking. There are few problems which are beset with more experimental and theoretical difficulties than this one. In the first place, to some the term itself bears connotations of anthropomorphism and teleology; however whether this is a "good" or "bad" characteristic of phraseology is not an issue to be solved here. Secondly, the problem is complicated by physiological variables which are difficult to control even roughly; furthermore those internal conditions which may be fundamental to the drive are complexly inter-related with other spheres of organic and behavioral factors; that is, the interdependence and interaction which characterize the relationship among the various "vital systems" make it impossible to isolate the variable as such. Thus the experimentalist is forced to be content when he is able to gain no more than a rough control over any of these factors.

After the experimentalist has imposed the most rigid controls possible and turns toward an explanation of his results, he finds himself facing even greater and more serious difficulties. It is one thing to control the operations

through which motivation can be varied and it is still another thing to describe and explain those non-observable variables which are also involved. It is impossible to differentiate between the physiological "drive status" of an organism and the "cognitive sphere" except at the level of relatively rough description. Just what properties of the "drive" are initiated through cognitive processes, and the converse, namely, what properties of the cognitive realm are determined by the drive status, is an impossible question to answer. Although by experimental manipulation one can approach an answer to this question, in a specific case, in terms of "more than" or "less than", a rigid quantitative separation of the two factors is logically unsound. Learning and motivation are not two separate processes; they are two aspects of the same process. If one separates the two in a learning situation, he simply gives one process two names and arbitrarily calls one the cause and the other the effect--motivation the cause and learning the effect. If motivation is the cause of learning, then the converse is also true, namely, that learning is the cause of motivation. This, of course, makes the two interdependent--each is simultaneously a cause and an effect. It is logical to think of the problem from this point of view.

In the present study, the motivational factor is even more complicated. This added complication arises from the fact that we are dealing with a difference between the performance of two groups which have been subjected to identical

external conditions, excepting temperature; therefore, if motivation, as a dependent variable, were varied, this variation would come about along with as well as because of conditions which were impossible to control. It is certainly possible to determine the relative effect on maze performance of varying degrees of food deprivation if all other conditions are held constant. However, in the present investigation, it was impossible to hold these conditions constant. There is a vast difference between manipulating the "food need" through food deprivation and manipulating the "food need" through temperature variations.

Thus one might test hot and cold room rats in a grill experiment to see which group more readily submitted to an electric shock to secure food. One might find that the cold room rats would submit to greater shock. If this were true, will they take more shock because they are more hungry, or because they are more intelligent, or both? It is a well known fact that in general the more intelligent races are also the more aggressive. In innumerable ways they reveal, in the long run, higher levels of motivation.

Theoretically, it would be possible to frustrate an individual hot room rat, in a concrete situation through fear, and find that it would react more violently than a cold room rat, and yet the hot room rat reveals every evidence of living, in general, at a lower energy level. Furthermore, theoretically, it might possibly be found that what, in specific situations, would appear to be highly motivated

behavior in the hot room rat was, as well, a symptom of instability in the total behavior pattern, a temporary erratic outburst of energy, rather than the consequence of a "steady drive". Thus, in the grill experiment, should the hot room rat submit to greater shock, would this be the result of motivation as an isolated factor, or, of instability, such as may be found in the savage, in a "fanatic" state? Such are the difficulties of functional analysis, regardless of its desirability.

Let us consider briefly the total pattern of physiological changes which are brought about through a change in temperature level. As was pointed out in Chapter II, cold temperatures increase the metabolic rate, increase vasomotor constriction, shift the pH to the alkaline side, increase sympathetic stimulation, increase the muscular irritability, increase the mucous membrane secretion, increase the production of glycogen, and increase the efficiency of its utilization. Warm temperatures cause the physiological status, in general, to shift to the opposite pole. These two respective patterns of intervening variables appear concomitantly with the differences in behavior between the two groups of rats. Just what relationship the "food drive" bears to this pattern is the issue at stake in this discussion. The "food drive" variable is inter-related with this whole "complex of variables". The effect of any one of these on behavior cannot be isolated because its effect is mediated through the "over-summative" property of the total physiol-

ogical pattern. Furthermore, if a change takes place in any one of these variables, the nature of the total pattern, of necessity, changes. The "drive status" of an organism cannot be changed without concomitant variations in the other variables.

As was pointed out in Chapter III, in preparation for maze running, the rats from each room were deprived of food for the same length of time (24 hours). If this same condition for each group resulted in making the cold room rats more hungry than the hot room rats, then it can be said that the former were probably, in the long run, more highly motivated. Nevertheless, it is well known that both animals and human beings show more insight in crises, so that it would appear that the higher energy level of the cold room rats was probably manifested in both ways, more "drive" and more "insight". At the same time, both, in this situation being a consequence of a general tension. Whatever the answer, the differential hunger drive, if there were one, was obviously a direct consequence of temperature differences, since it varied consistently with temperature. In the end, temperature was the controlling factor.

Since the cold room rats were superior to all other groups in maze performance, does it mean that the cold room rats were more "intelligent"? If we define intelligence in terms of maze performance, then the answer to this question would be in the affirmative; however, whether or not we call one

group more intelligent than another does not make our results more significant and meaningful. To label this behavior has not been the purpose of this study. We are content, and even prefer, to speak of the group differences simply in terms of "efficiency of maze performance". Under a given set of conditions the cold room rats were more efficient in terms of maze performance. It is quite impossible to say, for example, that a certain percentage of the difference was caused by more intelligence and that the remaining percentage was caused by greater motivation.

This study has been concerned with demonstrating those relatively gross behavior differences which appear as the result of temperature variation. The nature and number of the intervening variables involved present problems for further study. Our results should also serve to emphasize the importance of controlling the factor of temperature in animal experimentation. The results of those experiments in which temperature was not controlled are to be seriously questioned.

Suggestions for Further Study

The new problems which have been opened by this investigation are as important as the actual data themselves. Here we have been able to do little more than to clarify certain general and basic effects of temperature on behavior. Further studies in this realm will yield fruitful results. The following is a list of general problems which require further clarification and study:

(1) Since this investigation was concerned with relatively extreme temperature differences, the optimum temperature level for maze performance remains undetermined. A study utilizing a large series of temperature levels would do much toward clarifying this problem.

(2) The relative permanency of the effect on behavior of being born in a given temperature level needs to be determined. In other words, a study of the behavior of animals after being shifted from one room to another should be carried out. This could be done by shifting the animals from their home room to a room of a new temperature level; for example, by taking animals who were born in the cold room and placing them in the hot room.

(3) Since this study was carried through to the second generation only, nothing is known relative to the performance of future generations. Later generations should yield additional information with respect to the effect of temperature on behavior.

(4) The problem of motivation needs experimental clarification. In this connection such methods as the Columbia Obstruction Method should yield valuable information.

(5) The frustration technique of Maier should lend itself well to a clarification of the problem relative to qualitative behavior differences--differences in emotional stability and the like. In light of the peculiar qualitative maze behavior which was exhibited by many of the rats from

the hot room, this technique should give added insight into some of the conditions of "neurotic" behavior.

(6) General observations of cage behavior strongly suggested that there were significant "social behavior" differences.

(7) Our results give adequate reason for supposing that there are wide emotional differences between hot and cold room rats. Here controlled studies are needed for substantiation.

(8) Casual observations which were made during the progress of the experiment indicated a difference which existed among the groups in rate of behavior development. More studies of the development of behavior are needed.

(9) Many physiological problems remain to be answered.

Summary and Conclusions

(1) Three colonies of white rats were raised under the temperature conditions of 55°, 75°, and 90° F respectively. The study was carried through two generations. 150 rats from each generation were used as subjects.

(2) Weekly weight records were taken and growth curves were plotted.

(3) At 21 weeks of age, the rats were killed and tail- and body-length measurements were made. Body-length: body-weight and body-length: tail-length ratios were computed.

(4) At 80 to 95 days of age, 45 rats from each room were started on the initial training in the maze. One-third of the rats from each room learned the maze in one of the three temperature conditions. Records of time, errors, and trials

were kept.

(5) 30 days after having learned the maze, each rat was tested for retention.

(6) In the cold room, the rats grew most rapidly, matured earlier, and gave birth to litters of larger, healthier young.

(7) In the hot room, growth and maturity were much delayed; conceptions took place later; the young born were small; and many of each litter died shortly after birth.

(8) The hot room rats were of smaller adult size and had an average tail-length fully one centimeter longer than those in the cold room. Significant morphological differences were noted.

(9) According to the three criteria of learning, the subjects from the cold room were from two to three times more efficient in maze performance than the subjects from the hot room. The cold room rats were also superior to the control room animals. The cold room rats running the maze in the cold room required an average of 13.6 trials, 113.4 errors, and 4,857 seconds to learn the maze as compared with the hot room rats which required an average of 53.9 trials, 258.8 errors, and 10,579 seconds. The control room rats placed themselves about mid-way between these two extreme groups with an average of 21.7 trials, 123.9 errors, and 4,005 seconds.

(10) Both the temperature of the room in which the rat learns the maze and the temperature of the room in which he was raised were found to be important conditions in maze performance.

(11) In retention there appeared to have been no significant difference in terms of percentage saving; however the hot room rats required several times as many trials to re-learn the maze.

(12) Significant qualitative differences in maze behavior were noted.

(13) Within the limits of the experiment adaptation to climatic conditions appears to be continuous and accumulative from one generation to another. This was demonstrated in the case of both maze performance and morphological characteristics.

(14) In considering the cause of the differences in maze performance, the possibility of motivational factors was discussed.

(15) The implications for further research were pointed out.

(16) It is concluded that temperature is an important condition of the efficiency of maze learning in the white rat.

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APPENDIX

Learning Curves

The learning curves of time and errors plotted against trials which appear on the following pages were plotted from composite data. The average group scores for trials and time respectively, were obtained by dividing the total group score by the number of rats which remained in the group at the particular stage of learning in question.

These curves were plotted from the data of the first generation. Learning curves for the second generation were not worked out because there was little difference between the first and second generations.

Since the latter portion of any one curve is not representative of the performance of the entire group, these curves are of value only in making gross comparisons. The number and percentage of the rats in each group which were running at a given stage in the course of maze experiments can be obtained by referring to the following data. This information is given for the nine groups, Cc, Cx, Ch, Xx, Xc, Xh, Hh, Hx, and Hc, respectively. The letter-symbols are used here as they were in the previous pages of this thesis.

Cc

Trial	Number	Percentage
1-8	16	100
9	15	93.8
10	14	87.5
11	12	75.0
12-13	11	68.8
14	10	62.5
15-16	9	56.3
17	8	50.0
18	5	31.3
19	4	25.0
20-22	3	18.8
23-24	2	12.5

Cx

Trial	Number	Percentage
1-10	16	100
11	15	93.7
12-15	13	81.3
16	12	75.0
17-21	11	68.8
22-24	10	62.5
25-26	9	56.3
27	8	50.0
28	6	37.5
29	5	31.3
30-33	4	25.0
34-35	3	18.8
36	2	12.5
37-41	1	6.3

Ch

Xx

Trials Number Percentage

1-12-----17-----100
 13-15-----16----- 94.1
 16-17-----14----- 82.4
 18-22-----13----- 76.5
 23-25-----12----- 70.6
 26-27-----11----- 64.7
 28----- 9----- 52.9
 29----- 8----- 47.1
 30----- 7----- 41.2
 31-35----- 6----- 35.3
 36-38----- 5----- 29.4
 39----- 4----- 23.5
 40-47----- 2----- 11.8
 48-49----- 1----- 5.8

Trials Number Percentage

1-9-----15-----100
 10-----14----- 93.3
 11-18-----13----- 86.7
 19-----11----- 73.3
 20----- 9----- 60.0
 21-22----- 8----- 53.3
 23-27----- 7----- 46.7
 28----- 6----- 40.0
 29-30----- 4----- 26.7
 31-33----- 3----- 20.0
 34-41----- 1----- 6.7

Xc

Trials	Number	Percentage
1-14-----	15-----	100
15-17-----	14-----	93.3
18-----	13-----	86.7
19-24-----	12-----	80.0
25-----	11-----	73.3
26-----	9-----	60.0
27-----	8-----	53.3
28-29-----	7-----	46.7
30-32-----	6-----	40.0
33-39-----	4-----	26.7
40-41-----	3-----	20.0
42-44-----	2-----	13.3

Xh

Trials	Number	Percentage
1-12-----	15-----	100
13-----	14-----	93.3
14-18-----	13-----	86.7
19-21-----	12-----	80.0
22-23-----	11-----	73.3
24-----	10-----	66.6
25-26-----	9-----	60.0
27-30-----	8-----	53.3
31-35-----	7-----	46.7
36-----	6-----	40.0
37-38-----	5-----	33.3
39-----	4-----	26.6
40-----	3-----	20.0
41-54-----	2-----	13.3
55-----	1-----	6.7

Hh

Trials	Number	Percentage
1-24-----	12-----	100
25-31-----	11-----	91.7
32-34-----	10-----	83.3
35-37-----	9-----	75.0
38-47-----	8-----	66.7
48-51-----	7-----	58.3
52-----	6-----	50.0
53-55-----	5-----	41.7
56-68-----	4-----	33.3
69-75-----	3-----	25.0
76-96-----	2-----	16.7
97-100-----	1-----	8.3

Hx

Trials	Number	Percentage
1-10-----	12-----	100
11-29-----	11-----	91.7
30-34-----	10-----	83.3
35-----	9-----	75.0
36-40-----	8-----	66.7
41-43-----	7-----	58.3
44-----	6-----	50.0
45-53-----	5-----	41.7
54-58-----	4-----	33.3
59-66-----	3-----	25.0
67-84-----	2-----	16.7
85-100-----	1-----	8.3

Hc

Trial	Number	Percentage
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1-14	11	100
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15-35	10	90.9
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36-42	9	81.8
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43-44	8	72.7
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45	7	63.6
----	---	------

46-47	6	54.5
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48-71	5	45.5
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72-88	4	36.4
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89-100	3	27.3
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Errors

Errors

Errors

Errors

Errors