EARLY EXPERIENCE IN THE GOLDEN HAMSTER : A FAILURE IN CROSS-SPECIES APPLICABILITY

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ABSTRACT

The rapid spread of interest and experimental work in early experience has led to confused and contradictory claims. This thesis reviews the literature to assess these claims and investigates certain hypotheses. Experiments were designed to test (1) the effects of neonatal stimulation, (2) the effects of pre v post-weaning environments, and (3) the effects of handling in the golden hamster. This experimental animal was used to determine cross-species applicability of infantile stimulation theory.

Experimental work consisted of submitting litters to early "burrow" or laboratory environments preweaning, and to laboratory or free-enriched environments postweaning. Other litters were subjected to various handling schedules - days 1-21, days 1-4, days 5-21 and "non-handled" controls in order to understand the contradictory results reported. Dependent variables included, physiologically, growth observation, brain and adrenal weight analysis, and plasma cortisol assay; and, behaviourally, open-field behaviour, response to novel objects and discrimination learning ability: all variables typically used in this field. The data were subjected to analysis of variance.

Results show early stimulation in the golden hamster to have none of the "beneficial" effects found in the rat; rather it leads to increased emotionality, neophobia, impaired learning and poor physical development. These effects cannot solely be attributed to impaired hypothalamic maturation nor alteration in maternal care, as demonstrated by the handling conditions. Both early "burrow" environments and later free-enriched experience effect clear adaptation in the subjects with decreased emotionality, faster reactivity and good learning ability; the early environment affected physiological changes within the animal, whilst the enrichment produced its effect via experiential factors.

Wider usage of species, taking into account their known natural history, and a more ethological experimental approach appears necessary to gain a true understanding of mediators and their consequences in this field. No extrapolation to higher organisms is valid at this stage.

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I. INTRODUCTION

I. INTRODUCTION

The research reported in this thesis was originally devised to clarify certain issues arising from the abundant literature available in the field of early experience. The behaviour of any adult organism depends upon both the experiences obtained from the environment during certain periods of development and on some genetically preordained limitations of plasticity, as well as the present conditions. The study area with which I am concerned is the former, which has been a rapidly expanding area of interest since the initial experimental procedures of Levine (1956) and Denenberg (1959) highlighted just how dramatic the environment's effect upon a developing organism could be.

It has long been believed that the environment influences one's behaviour, personality and underlying physiology both directly (as in 'fight or flight' response) or indirectly (as in 'executive monkeys') and that this relationship could be explored until every nuance was understood. The usefulness of such an investigation is highly doubtful but when one has a specific variable such as handling, that lends itself to study, the rewards appear greater. The confusion that has arisen from the resulting experiments, however, is as bad as one might have feared. Such a vast range of dependent and independent variables have been utilised that, together with the sweeping generalisations made in conclusion, they have led to a bewilderment over the numerous paradoxes, assertions and counterassertions - at least on my part. The original surmise about the technique - that one could pick up a young animal daily pre-weaning, and so irrevocably alter its adult emotionality, intellectual ability and physiological growth by some common and presumably simple pathway - seemed so clear.

Obviously the 'doing anything' explorative technique must be undertaken once started in order that future workers may have a total picture; but the present problems seem to have arisen from a lack of clear understanding by researchers as to why experiments are being conducted - it's the early experience bandwagon and we all joined before rhyme and reason could play their part.

An example of this lack of reasoning is contained in a paper by Wyly, Denenberg, Santis, Burns and Zarrow (1974) which detailed a study into the effects of handling rabbits in infancy in an attempt to compare them with rats and thus show...."a broad base for generalizing principles". We have, then, two distinct species from different orders and one wishes to see if the same experimental principle, when applied to both, produces comparable results - the basis for any investigation in comparative psychology. The apparent principle under study is basically: if a neonate is handled daily until weaning is its behaviour when adult affected. However, the actual principle investigated may be better stated as: if a neonate is handled for days 1-20 is its behaviour affected at 45-50 days of age - this being the actual temporal patterning of the handling technique commonly employed, as in rats. The former principle is obviously a more meaningful one to investigate as the latter is strictly derivative from the laboratory procedure with little established relevance to the world outside.

By comparing Wyly et al's paper with one dealing with the handling procedure in rats one finds neither of these principles being tested. The rabbits were subjected to daily handling days 1-20 (i.e. the latter principle is apparently under investigation as rabbits are not normally weaned until 30 days at the earliest); and then their behaviour is tested when they are 30 days old, immediately postweaning (neither waiting for sexual maturity nor testing at 45-50 days). Although the results are in fact fairly comparable to those of rat experiments - i.e.: decreased emotionality, increased activity and greater exploration due to an interest in novelty nothing is known of the effects, if any, observed in the mature animal (whose behaviour is almost certain to differ in some respects from that of the juvenile). Without a proper experimental design a valid comparison cannot be made.

If even these experienced experimenters loose their grip on essentials is it surprising that a situation has been reached in which few experiments can be meaningfully compared because of the wide range of strategies employed involving strain, stimulation intensity - both relative and absolute, developmental conditions within a species, variation in normal laboratory conditions both during the experimental stage and the testing stage of the research, apparent haphazard selection of dependent variables and so forth. These hazards to correct interpretation are often complicated by a failure to report both experimental details and insignificant results (see Geller in Sterman, McGinty and Adinolphi, 1971).

Time, and awareness of the problem, may resolve these inconsistencies;

in one of the many reviews now available, Daly (1973) makes the point that the reasoning behind these studies and their conclusions is frequently at fault due to a misplaced anthropocentric orientation. Bearing in mind these remarks this research has attempted to clarify some of the general relationships between behaviour and physiology, altered by early experience; and to test Daly's hypothesis concerning variable levels of stimulation. An uncommon experimental animal, the golden hamster, was used in an effort to clarify the limits of the alleged 'broad principles' at present accepted by many workers.

The thesis includes a review of the relevant literature together with an appraisal of the usefulness of the golden hamster as an experimental animal.

II. EARLY EXPERIENCE

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The term early experience in this thesis is used in the narrow sense, often referred to as 'infantile stimulation', rather than its wide general sense. Infantile stimulation may itself seem an unusual terminology as many of the techniques used in this field are not strictly stimulating, such as deprivation experiments. However, they are all non-normal and in this sense they are therefore stimulating to the organism being studied. An inherent problem in such research is that of defining and understanding the 'normal' so this, at present, will be taken to mean the standard rearing conditions of the laboratory animal since the majority of research and formulation of ideas is based on animals so reared. The contention that in this sense 'normal' might not necessarily mean the optimum must be recognised from the start.

Historically, ideas concerning infancy having any significant effect on adult behaviour first began gaining credence during the 1920's, but it was not really until during the 1950's that any substantial work was begun using experimental animals. Much of this early work, such as effects of gentling, handling and restriction, was summarised by Beach and Jaynes (1954) and there are now comprehensive reviews of many aspects of this field. The following sections do not attempt to emulate these reviews (see Denenberg; 1962b, 1964, 1967, 1972; Levine 1962b; Newton and Levine 1968; Ambrose 1969; Daly 1973; Bindra 1957; Ader 1959, 1966) but simply state the present position and to discuss those areas relevant to this research.

The field of study termed 'early experience' or 'early stimulation' covers a wide range of experimental conditions including direct preweaning manipulation (in the form of handling, shocking or other physical intervention), preweaning intervention mediated via affected maternal or even grandmaternal behaviour(this can include such variables as nutritive status and also prenatal condition), and both pre- and post-weaning environmental manipulation. The vast range of this field - which has been an extremely active research area for the past two decades - has led to some confusion and, in an attempt to define broad principles, the derivation of somewhat controversial interpretation. Indeed, even as early as

1958, King stated in his review that "....the experiments as a whole reveal a lack of attention to variables other than the one being manipulated".

It has become widely accepted that such manipulation has adaptive consequences for the organism, and that these are beneficial. The benefits, produced via some aspect of the physiological 'stress response' mediated through the hypothalamic - pituitary - adrenal axis, are generally accepted to be of four main classes: (i) the promotion of growth and the acceleration of physiological and behavioural development; (ii) the reduction of emotional reactivity in the adult, especially to novel stimuli; (iii) the improvement of performance in learning tasks, especially in aversive situations; and (iv) the alteration of physiological responses to stresses in adulthood. These effects are accompanied by normally permanent changes in the animals physiological make-up.

A report made by Bernstein (1952) which stated that handling of the laboratory rat by the experimenter for a few minutes daily led to better performance on maze tasks in the adult could be said to have initiated the investigation into early handling phenomena, although early workers, such as Weineger (1953), typically did not use animals before weaning. However, their results were in many ways similar to those obtained using younger experimental animals (such as the improved learning found by Bernstein and the increased weight gain, greater viability under food and water deprivation, and decreased emotionality as measured by open-field ambulation found by Weineger). The explanation given by Bernstein was based on a combination of learning theory and personality theory which emphasised the formation of a relationship between S and the experimenter, and hence reinforcement during testing. Weineger, however, more influenced by Selye's stress theory (1950) and Hebb's theory of brain mechanism development with regard to early experience (1949), proposed handling to be a 'gentling' technique (analagous to the importance of 'tender loving care' in human infancy) which affected the maturation of developing emotional or 'stress' centres in the hypothalamus.

Other early experiments by Levine (1956, 1957) utilised the handling technique in the same form as it is now used (although it was originally designed as a secondary control condition) with rats aged 1-20 days and found (i) increased body weight and accelerated weight gain; (ii) quicker and faster gross physiological response to stress, as measured by adrenal steroids, with a faster decline, accompanied by a smaller increase in overall adrenal gland size in response to a stressor in the form of a glucose injection; (iii) improved survival when deprived of food and water; (iv) a raising of the emotional reactivity threshold as shown by increased open-field ambulation; and (v) improved adult conditioned avoidance response learning to electric shock. Increased secretion of ACTH and ADH was implicated by this early work leading to Levine's interpretation that the lower emotionality shown by these animals in a 'trauma' situation was the result of a modified stress reaction, produced by an alteration in the reactivity threshold within the central nervous system as a result of previous exposure to trauma, i.e. handling.

Superficially this appears to be the same position as accepted at the present time, and much work was initially concerned with replicating these findings and then extending the possible dependent and independent variables that could be utilised. However, a closer study of the facts - together with evidence from other species - reveals nonsupportive as well as supportive data.

When it was shown (Levine and Otis, 1958) that handling before weaning was much more effective than postweaning handling many workers attempted to define a critical period within that time for handling effects to be maximal; see Schaefer, in Newton and Levine (1968); Denenberg (1972); and Scott (1968). Despite many results emphasising the importance of the first week most workers now agree that there are probably as many critical periods as there are variables. In his review of the subject Denenberg (1968) concluded that although the age of stimulation was an important parameter there were other equally important parameters including the quantity of stimulation; the quality of stimulation; the particular dependent variable measured; the particular quantitative parameters of the dependent variable; and the animals experiences between initial stimulation and testing. This indicated that it was more reasonable to study the functional relationships between the various classes of independent and dependent variables utilised between birth and weaning than to design experiments which try to isolate critical periods during the developmental period between birth and weaning.

A point which must be remembered when making cross-species comparisons is relevant at this stage, that is - that in the different species the maturation rates, both overall and for different processes specifically, differ, which could result in the early stimulation affecting these processes at different stages of development.

Many of the results from experiments designed to isolate critical periods also revealed that there appeared to be an optimum level of stimulation in that one often obtained an inverted U-shaped relationship between the amount of stimulation received and the change produced in the dependent variable under study, (Smith, 1967).

The other major area of study has been involved in determining how these effects are mediated. Many experiments carried out showed the wide generality of effect produced by an apparently unrelated number of stimulative techniques - such as: handling, shocking, temperature changes, physiological intervention, and environmental changes. This diversity amongst the independent variables makes it very difficult to arrive at a single mechanism which is being affected - as stated by Daly (1973) '....the stimulation effects can be produced through various mechanisms, and most experimental treatments probably act through more than one.' Russell (1971) proposes four major modes through which the effects are produced - these being:

i) direct stimulative action -

This typically includes the tactile methods of stimulation and may also, despite Russell's suggestion that they were ineffective, include visual and auditory stimulation as well. A disadvantage with experiments involving the visual modality is that they usually involve prolonged treatment beyond weaning. Gibson, Walk and Tighe (1959), Walk (1960) and Tees (1969) all found evidence of increased emotionality in dark-reared rats whilst Lockard (1963) showed variation in adult body weight. Auditory stimulation also produces typical 'handling' effects in rats although mice show variation in effect due to strain, see Lindzey, Winston and Manosevitz (1963).

ii) hypothermia -

For a time this was argued to be the important variable (Schaefer, 1963 and in Newton and Levine, 1968) but it has now been established as only one of the mechanisms by which the effects may be produced. Indeed, Haggett and Werboff (1968), Hess et al (1969) and Thoman and Levine (1969) have all shown handling effects with and without actual handling by controlling temperature alone. However, as this is a clear-cut measureable occurrence (i.e. temperature loss) there has been quite extensive work carried out allowing several parameters to be investigated and delineated (see Chevillard, Porter and Cadot 1963; Schaefer, 1963; 1968b; Hutchings, 1963, 1967; and McIver et al, 1968).

iii) maternal behaviour -

A vast literature shows maternal manipulation (whether during her own youth, during pregnancy or after parturition) produces effects in offspring in many of the variables considered functionally related to early experience. However, the mediation of the female in producing these effects has been gaining more support in recent work (see Williams, Bailey and Lee, 1975). As well as being affected herself by the procedure the female is responsive to subtle properties of the offspring and alters her behaviour towards differentially manipulated pups.

iv) early stress -

As one of the effects of early stimulation is to alter the animals stress responses it is accepted that this is one mechanism which is brought into play, and may indeed underlie all the other mechanisms. The physiological changes associated with early stimulation have been well investigated, with many workers using physiological measures rather than behavioural ones.

In more recent literature the use of environmental and nutritional variables (such as undernutrition, eg. Smart, 1976 ; enriched and restricted environments, Rosenzweig et al, 1972) is favoured in experimentation to produce 'handling' effects. This appears a step in the right direction as it is dealing with the problem from a more reasonable position, in that it is no longer a purely manufactured laboratory procedure but one with relevance to the normal life of many species, including man. One may also in this way pick up the more stable, but no less important, parameters. A point to bear in mind, however, is that, on reading some papers one meets the same problem emphasised by King in 1958 (see above), with experimenters denying the importance of variables other than the specific one under investigation. For example, in an experiment of environmental manipulation (Morgan 1973) the footnote saying "... all animals within this experiment were handled to reduce effects from testing and other variables with no bearing on the question under investigation" is disheartening. This rather narrow view should surely be limited to the grosser sciences of medicine and physiology, rather than the more illusive study of animal psychology. This is particularly true in such environmental studies where the effects are often fairly subtle and often greatly interrelated. The fact that studies now show the continuing nature of these manipulations, in that the environmental condition has a differential effect upon the animal between the experimental event and the test procedure, rather than assuming the organism is static once removed from that condition lends emphasis to the importance of plasticity on the part of the experimenters (see Inglis, 1975; Essman, 1971).

There seem to be a great many hypotheses chasing too few facts in all of these studies. Quite apart from the rather haphazard collection of experimental variables there is the additional problem that many of the dependent variables studied seem to have been just as randomly chosen because no close knit body of theory joins together the hypotheses under investigation and the observations made. The fact that the initial discovery that 'handling' in infancy had such pronounced and long term consequences was itself almost accidental may have something to do with the lack of cohesion in subsequent work - there is very little in the way of theory to direct the observations.

By contrast the more physiological work takes place within a fairly tight theoretical framework in which there is a clear set of predictions to be made and observations to be carried out. The way in which hormonal function may be studied is much more clearly mapped than the plan for behavioural observations. Since the work of Selye on stress adrenal physiology in particular can and does demonstrate the truth of Miyado and Hisada (1975) observation that "The hormonal milieu in the neonatal period has profound influences on the morphological, biochemical and functional development of the brain".

This in essence sums up the physiological background to the present study which is detailed in the next section. The relevance of this work is more obvious than some of the psychological work because it is less speculative and more inherently bound into an accepted scientific model. It makes a background against which even some of the more arbitrarily chosen behavioural variables could be seen to be theoretically related to one author in a meaningful way.

PHYSIOLOGICAL BACKGROUND:

The physiological explanation that has been determined to underlie the production of behavioural effects by the handling technique involves the neuroendocrine stress response of the pituitary-adrenal cortex homeostatic loop. This basic physiological reaction of mammals - known as the stress syndrome, and originally described by Selye (1950) - occurs whenever information concerning a stress (or 'stimulation') whether somatic or psychological, is received by the CNS. Although there is some disagreement over finer points of the pathways of this response, it is now generally accepted that the basic pathway consists of the secretion of corticotropin releasing factor (CRF) from neurosecretary cells in the median eminence region of the hypothalamus, as a result of CNS stimulation. The CRF is transmitted via a venous network, known as the pituitary portal system, to the anterior pituitary. As a result the pituitary secretes ACTH to stimulate the adrenal cortex to increase synthesis and secretion of corticoid hormones, which are responsible for the metabolic adjustments necessitated by exertion or exhaustion as would occur in a stressful situation. The portal capillaries appear essential for central regulation of ACTH secretion in response to changing body needs although the pituitary alone is capable of maintaining basal levels of ACTH (Schapiro 1968, in Newton and Levine). The steroid output to the blood is monitored by a feedback system within the CNS until a functional equilibrium is achieved. The feedback between the pituitary and its target organs is affected via the level of circulating hormones which reach the CNS and the anterior pituitary via the superior hypophyseal artery. The CNS control overall is highly complex involving various limbic areas and only now beginning to be fully understood (Azmitia, 1975; Bassett <u>et al</u>, 1973; Montgomery and Berkut, 1969; DeWied and Weijnen, 1970). This system was initially implicated by findings of altered adrenal size and resistance to stress (Levine, 1962a) and it is now often taken as the sole explanation for the phenomenon.

The time scale of the stress is important in producing the overall result - with a single, short stress one gets a fairly clear-cut 'alarm reaction', whilst with chronic stressors the alarm reaction

Footnote: The responses discussed here are those occurring either generally, or specifically within the rat, as research has mainly focused on using the rat as an experimental tool. Where there may be differences in other species they will be detailed in the comparative section.

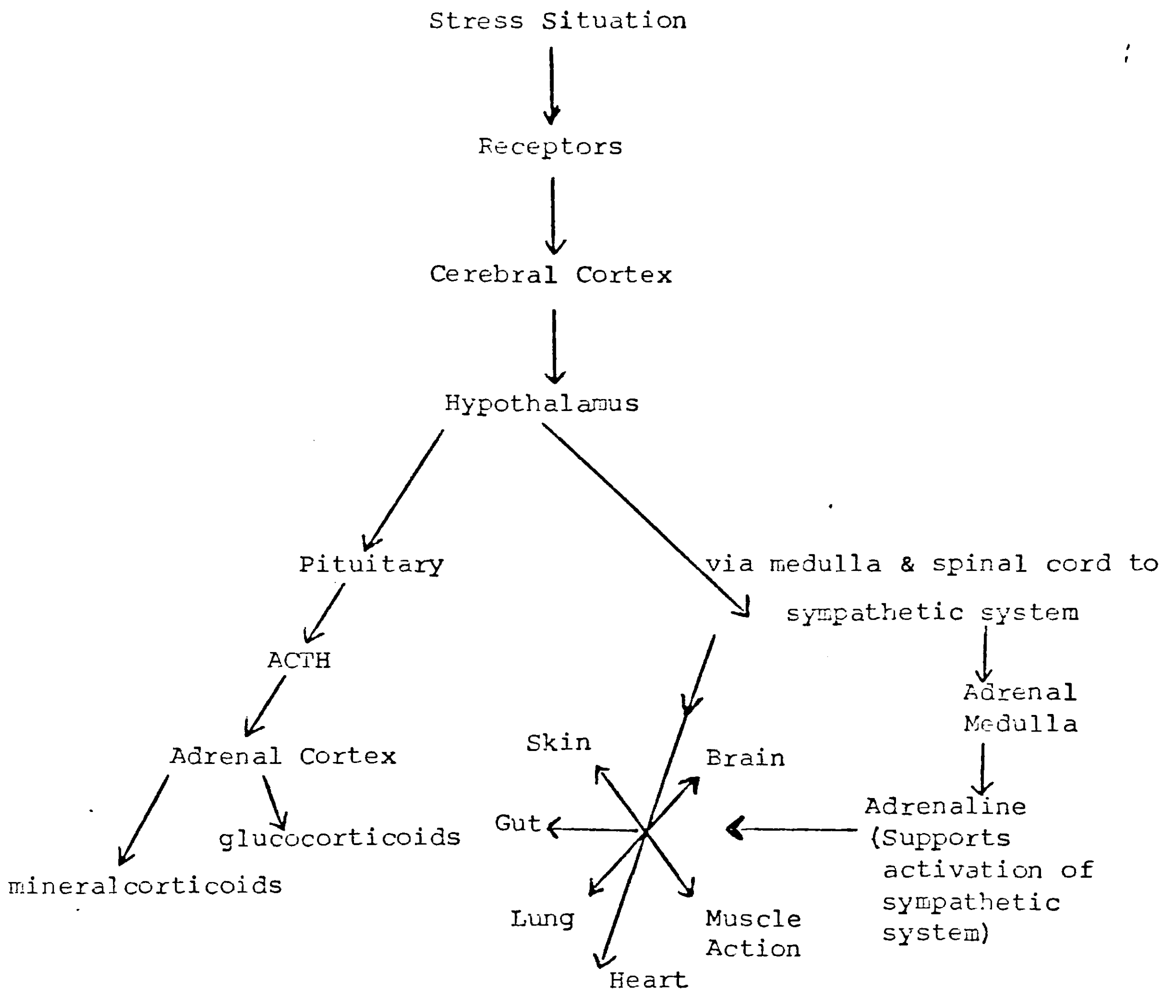
gives way to a stage of resistance to the stress, followed eventually by a stage of exhaustion with a catastrophic decline in resistance to all forms of stress. This is known as Selye's (1950) general adaptation system, or GAS. It does therefore seem necessary to differentiate between experimental techniques that involve a discontinuous stimulation, such as handling, and those that involve a continuous stimulation, such as environmental manipulation.

It is interesting that whilst the activation of the sympathetic nervous system is well-implicated in an alarm reaction it is rarely considered in connection with early experience effects. Secondly, the fact that many alarm reactions are typically associated with chemical or visual social signals (Altman, 1967) amongst members of groups of many species also bears consideration. This may be a possible explanation for the differential effects produced by handled pups on maternal responsiveness.
The point which seems to be overlooked by many psychologists is that stress does not solely operate via a CRF-ACTH-corticosterone feedback system, but may also cause the secretion of other hormones in order to produce a total endocrine response (Sayers, 1950). Similarly, in the activation of the adrenal gland many other steroids which affect metabolism may be affected. Early evidence (Swann, 1940) suggests that the degree of pituitary control on adrenocortical function is rarely complete.

The fact that there is a neural response via the splanchnic nerve to the adrenal medulla, as well as an hormonal one, to emotional disturbance has been known since first proposed by Cannon (1929) although Edens and Siegel (1975) point out that the overall response in an individual species may depend on their different abilities to maintain responsiveness to the imposed stress. In addition to adrenal medullary and cortical responses, the hypothalamus itself appears involved in variations in the electroyte balance, which may be imbalanced for up to one week in acutely stressful situations.

SEQUENCE OF EVENTS IN THE BODY'S REACTIONS TO STRESS SITUATIONS SUCH AS DANGER OR COLD

Activation of the adrenal medulla precedes that of the cortex.



Lead to conservation activities which give added ability to withstand stress.

Rapid mobilisation of body resources to meet stress.

Figure taken from "The physiology of mammals and other vertebrates" by Marshall and Hughes (1967).

Starting with the anterior pituitary, or adenohypophysis, and looking at the system in more detail, the importance of this endocrine gland is inescapable. Although there are three main sections the major one is the pars distalis which is thought to secrete most, if not all, of the hormones so far isolated. These include the somatotrophic or growth hormone (STH), the corticotrophic hormone (ACTH), the thyrotrophic hormone (TSH), the lactogenic hormone or prolactin (LTH), the follicle-stimulating hormone (FSH) and the lutenizing hormone (LH). This gland is therefore involved in almost all vegetative processes, interacting complexly with virtually all metabolic and reproductive hormones and its removal, particularly in young animals, has drastic effects. These include an arrest in growth due largely to the cessation of skeletal development; atrophy of the adrenal cortex and thyroid; serious disturbances in carbohydrate protein and lipid metabolism; and, as a result, a greatly shortened life expectancy. Specifically, with regard to the stress response, both adrenal cholesterol and ascorbic acid (both corticoid precursors) are unaffected by stress following adenohypophysectomy. Despite having no direct nervous connections, the adenohypophysis is well exposed to CNS influences via its portal system, sharing a vascular supply with the neurohypophysis (or posterior pituitary) and a common fluid space with the brain. Although much of the role of the anterior pituitary is concerned with homeostasis via negative feedback systems there is also evidence that it can modify the level of output of other endocrine glands (Altman, 1967).

The anterior pituitary contains chromophobe cells, which are thought to be cells which have already discharged their hormones, and chromophil cells, which contain granules of formed hormones ready for release. These chromophils may be subdivided into basophils, which secrete TSH, ACTH, FSH and LH; and eosinophils, which secrete STH and LTH. These hormones are released into venous sinuses and then travel via the hypophyseal vein to their target tissues.

The main target of the corticotrophin hormone (ACTH) is the cortex of the adrenal gland where it stimulates cortical steroid secretion. This may be demonstrated by an injection of ACTH which results in the growth of adrenal cortical tissue and increased secretion of hormones. This is reflected metabolically within the cortex by depletion of cholesterol and AAA, together with an increased phosphorus turnover. Similarly, adrenalectomy is followed by an increased output of pituitary ACTH demonstrating the homeostatic control in the system - a fall in corticoid secretion leading to a rise in ACTH secretion and vice versa. It is at this point that most workers in the field have chosen to take measures to indicate the state of the physiological system - e.g. levels of AAA, levels of adrenal cholesterol, plasma corticoid levels, etc. However, although AAA levels are a relatively good indicator, decreasing in concentration with stress, Pinchol et al (1949) state that the concentration of AAA "alone is not a reliable index of the functional state of the adrenal which has been subjected to a prolonged stress". As many early experience treatments are prolonged (e.g. environmental treatments) this caution is not totally irrelevant.

The hormones secreted by the adrenal cortex include glucocorticoids (e.g. cortisone, cortisol and corticosterone), responsible for carbohydrate metabolism and mineralcorticoids (e.g. desoxycorticosterone and aldosterone), responsible for the regulation of electrolyte and water metabolism; as well as various sex hormones. In all, the effects of the corticoid hormones are numerous and complex including increasing the conversion of protein to carbohydrate (gluconeogenesis); increasing the flow of gastric juice; potentiating autonomic reactivity; influencing the movement of sodium into and potassium out of, the intracellular compartment; mobilising calcium from bone; inhibiting lymphatic tissue and antibody production (e.g. total mass of lymphoid tissue has been shown to be inversely proportional to the activity of the adrenal cortex); affecting CNS excitability and cell membrane permeability; inhibiting inflammatory reactions, increasing the activity of certain tissue enzymes involved in protein metabolism, as well as other enzymatic adaptations (see Denyes and Horwood, 1960); controlling the levels of lymphocytes and eosinophils in blood; and generally decreasing resistance to infection.

It seems that the increased release of adrenocortical hormones does not result in an increased resistance to stress, as is generally implied, but rather in an increased ability for restorative processes. The most important salt-retaining mineralcorticoid, aldosterone, is not under pituitary control at all but is produced in the zona glomerulosa in response to sodium deprivation and reduced extracellular fluid volume.

The adrenal gland shows a diurnal variation in activity and responsiveness within this homeostatic loop, which may explain some of the differing results workers have found with regard to resting levels of hormones, stress responses, etc.
Continued hyperactivity of the adrenal gland results in an increased size proportional to the amount of ACTH released. In severe and protracted stress the structure and appearance of the gland becomes altered - there is gross enlargement and a loss of cytoplasmic lipid resulting in a colour change from yellow to reddish brown.

Under stress the activity of the pituitary-adrenal system is negatively correlated with decreased activity of serotoninergic systems in the limbic complex (especially the hypothalamus) (Vermes and Telegdy, 1975). That is, stress leads to a decrease in serotonin metabolism in the limbic system and an increase in activity of the pituitary/adrenal system. This seems to reflect the fact that much of the CNS control via the hypothalamus of the pituitary is mediated via serotonin axons.

Although ACTH is generally thought of simply in connection with activation of the adrenal cortex, particularly during stress responses, it has a number of other effects. These include involvement in simple orientation, habituation, extinction, acquisition of learning in both aversive and appetitive situations, and learning of avoidance responses. Much of this type of effect has been initially explained by the 'stress' involved in such situations - indeed, the activity of the pituitary/adrenal system has been shown to correlate with facilitated avoidance learning (i.e. faster acquisition and longer extinction occur with higher plasma corticosterone response to stress) and both basal and stress-induced plasma corticosterone levels have been shown to correlate with learning (see Johnston, Miya and Paolino, 1974).

The hormones of the pituitary/adrenal cortex axis were therefore thought to influence fear-motivated behaviour such as avoidance behaviour but only under conditions of frustration and not in general. However, studies using analogues or ACTH fractions have found one can specifically obtain one response, e.g. altered avoidance behaviour, without the other, i.e. corticotrophic effect. Although many of the above behaviours may be related to stressful situations it is interesting that they may be separated.

One of the initial effects of ACTH within a stressful situation is to produce arousal. For example, Delussi (1973) has shown in cats and pigeons that direct injection of ACTH into the CSF results in a typical yawning and stretching behaviour pattern, leading to ECG arousal. This arousal ability of ACTH is also shown by MSH (melanocyte stimulating hormone - a hormone with amino acids numbers 1-13 the same as ACTH, see Schally, Bowers and Locke, 1964) and an ACTH fraction amino acids - numbers 6-10. It has therefore a narrow specificity - to obtain corticosterone secretion one needs an ACTH fraction with amino acids numbers 1-21. Similarly, it can be shown that the ACTH fraction with amino acids numbers 4-9 leads to increased avoidance learning with virtually no endocrine activity (Witter and Verhoef, 1975). Different structures of ACTH peptides therefore have different behavioural activity and metabolic potency.

The manner in which ACTH, corticosteroids and behaviourally active ACTH analogues influence exploratory and avoidance behaviours involves mediation via brain catecholamines (i.e. noradrenaline, NA). It is suggested (Wiegart and Gispen, 1975) that this change in NA metabolism is via an elevation in the levels of intracellar cyclic AMP directly influenced by ACTH resulting in an increased release of NA from storage, although there is an indirect effect via corticosteroid receptor sites to deplete the CNS NA pool. Correlation has been shown between exploratory activity, habituation of exploration and extinction of avoidance with the uptake of corticosterone in the hippocampus (Endroczi and

Nyakas, 1975). The involvement of the midbrain limbic system in avoidance response has also been demonstrated by using lesions effects of ACTH, and also vasopressin (Urban and DeWied, 1975). Whilst vasopressin is involved with ACTH (particularly the behaviourally active part rather than the total) in avoidance behaviour, removal of the posterior lobe of the pituitary leads to a loss of avoidance response which is only restored by vasopressin (Thompson and DeWied, 1973). The importance of the presence and influence of vasopressin release is directly proportional to the intensity of an aversive stimulus.

The fact that vasopressin, a neurohumour released by the posterior pituitary which is under nervous control and influences the sympathetic nervous system, is involved in facilitating consolidation of avoidance behaviour and inhibiting the extinction of active avoidance, emphasises the importance of remembering that the body has several systems which are activated by any particular stimuli and not simply a hypothalamic - anterior pituitary-adrenal cortex response to all situations. It seems necessary to mention this due to the great deal of attention paid to that system by workers in the field of early experience. Indeed, it has been suggested that it is the activation of the sympathetic nervous system and the adrenal medulla that should be studied - particularly in situations involving only mild stress. Long (1952) proposes that this sympathetic activation leading to release of adrenaline also achieves rapid adrenocortical activation when necessary. Another link between corticosterone level and adrenal cortical activity with monamine metabolism is by the rate limiting activation to the cortical activity in monamine degredation. That is, inactivation of the cortex, which normally controls the activity of monamine oxidase and catechol-o-methyl transferase, leads to increased monamine metabolism which may only be reversed by glucocorticoid administration (Parvez and Parvez, 1975).

Overall, then, one has a set of interrelated effects which may act as a whole or in part with some evidence that certain parts of the ACTH molecule with no corticotrophic effect may in fact lead to an increase in the impairment of an avoidance response and delayed extinction (see DeWied et al, 1975). The fact that many of these effects are seen behaviourally in animals exposed to various early stimulation treatments suggests the possibility of different activation with different treatments rather than one single overall picture. The effect on types of exploratory and avoidance behaviour cannot, from the evidence, be simply related to variation in arousal (however measured) especially as ACTH activation may be blocked without affecting avoidance behaviour (Brain and Nowell, 1975).

As mentioned above, findings of altered adrenal size, adrenocortical reactivity and resistance to stress initially implicated the H-P-Adrenal cortex system in the physiological explanation for infantile stimulation effects. This reasoning was also employed in designating handling as 'stressful' (Denenberg et al, 1967) due to the release of corticosterone in 2-day old rats. The corticosterone, released from the adrenal after handling, is transported via the plasma to the brain and is especially concentrated in the hypothalamus (Haltmeyer et al, 1966; Denenberg, 1968). That finding led to the hypothesis that the released corticosterone acts on the developing brain to change many of the animals behavioural and physiological activities. This 'setting' of the animal's responses is thought of in an adaptive manner in that the animal is adjusting to its environment, whether that be internal or external (Denenberg and Zarrow, 1971; Levine, 1969). Dessi-Fulgheri, Lupo and Valeri (1975) have indeed shown the central action of corticosterone to vary in animals with different rearing experiences, due to modifications in the concentration of corticosterone receptors in the brain.

Grota (1976) supports the view that there is a change in the neural control of ACTH secretion in handled animals, resulting in a reduced adrenocortical reactivity, rather than a change in the rate of metabolism of corticosterone or the responsiveness of cortical tissues to ACTH. However, earlier data (Grota, 1975) does not support the hypothesis that ACTH in either the mother or the young mediates the effects of handling on subsequent adrenocortical reactivity and he suggests instead a neural mediation here also.

This may be connected with the sympathetic activation via the adrenal medulla involving the monamines, whose uptake are in turn controlled by Na^+ and K^+ balance (Bruinvels, 1975). Torda (1975) has demonstrated a connection between stress, the release of noradrenaline and the subsequent behaviour displayed, i.e. external stimuli are able to modify the neuroendocrine factors that underlie temperamental qualities as proposed by Levine and Alpert (1959). For example, changes in the homeostatic equilibrium of the neonate activates the hypothalamus and results in a release of noradrenaline (NA). This normally causes a distress call in the neonate as a signal for help, the stress is reduced and NA is synthesised to dopamine (DA) by tyrosine hydroxylase so relieving the situation. If the stress is persistent, there is a persistent release of NA which builds up in the CNS and, together with the resulting dopamine leads to a predisposition in the organism for aggression. If, on the other hand, the stress is intermittent, the release of NA is intermittent with some transfer of NA to adrenaline. These two hormones lead to a predisposition in the organism for anxiety. Alteration in the activity of tyrosine hydroxylase has also been clearly demonstrated as a result of early experience - with handling causing a significant reduction in activity of the enzyme in the adrenal gland (Pfeifer, Denenberg and Zarrow, 1973).

The overall picture from all these studies appears to indicate the importance of a wide, interdisciplinary study in order to evaluate the importance of the various mediating systems in behaviour - together with some attempt at interrelating these separate findings to provide continuum and flow between them.

To return to the question in hand, it was stated above that there is controversy and confusion due to the rapid expansion of interest in this field of study, the main points to be discussed are:

a) is there a "typical" effect of handling,
b) are these effects beneficial, and
c) what function do these effects serve?

(a) In an extensive review into the four main classes of effect - that is (i) the acceleration of development and the facilitation of growth; (ii) the reduction in emotionality; (iii) the improvement in learning ability; and (iv) the alteration of the physiological stress response axis - Daly (1973) found that whilst some of the 'typical' results of early stimulation may be accepted, even if one confines one's studies to the rat - the animal most commonly used for this research - results are not always replicable.

The contention that early stimulation accelerates development is well established with a number of indices such as CNS development (Levine and Alpert, 1959; Schapiro and Vukovich, 1970), pituitary-adrenal axis development (Levine, Alpert and Lewis, 1957, 1958; Ader, 1969), and sexual development (Morton, Denenberg and Zarrow, 1963); although early handling may also retard brain development (Altman, Das and Anderson, 1968). Dieterlen (1959), working with hamsters, showed that an olfactorily restricted environment retarded physical maturation although other responses were similar to that of controls. However, the conclusion that early stimulation results in a facilitation in growth appears based on an inadequate review of the data. Briefly, both shocking and handling have been shown in the rat to elevate weaning weight, (McMichael, 1961; Levine and Otis, 1958), reduce weaning weight (Denenberg and Smith, 1963) or to have no effect at all (Salama and Hunt, 1964; Denenberg, 1962a). Heat treatment tends to elevate weights whilst cold exposure has been ineffective (Werboff and Havlena, 1963; King, 1969). Similarly, handling of mice appears to have any one of these possible effects (Daly, 1973), whilst handling in hamsters has no effect (Scott, 1970). This confusion may be explained to a certain extent by variation in treatment details such as shock intensity, age of treatment and litter effects - but there remains the impression that there is no such thing as a typical effect (nor a strong, easily replicated effect) with regard to growth facilitation.

Reduction in emotionality is generally a real effect although open-field measures are not always supportive. Open-field ambulation is a poor measure unless trial length and number of trials are taken into consideration. Factorial studies suggest that the factor loadings are different when duration of trial and repeated trials are included as variables (Whimbey and Denenberg, 1967). The assumption that the internal processes giving rise to open-field behaviour are also different in simple or repeated trials, or change with trial duration seems fortified by these statistical observations. Defecation, at least in earlier trials, is a more reliable measure - in rats many workers have shown defecation to decrease with handling, although in mice the effect is nearly always an increase (Henderson, 1964, 1967; Labarba, Fernandez, White and Stewart, 1974). That early stimulation leads to more rapid habituation of fearful responses to novelty, and facilitates approach behaviour (Wells, 1975), is the most nearly unanimous general principle in this field of research. This occurs whatever the original direction of emotional change (Levine, Haltmeyer, Karas and Denenberg, 1967; Levine and Broadhurst, 1963; Salama and Hunt, 1964) which may indicate a learnt decrease in emotional behaviour following initial exposure to a novel situation, i.e. the open-field. Even very small amounts of stimulation very early in life (such as an injection in the first week of life, as used by Swanson 1967) have been shown to produce changes in emotional behaviour (Henderson, 1964; Denenberg, Morton, Kline and Grota, 1962).

Again, as with growth facilitation, on examining the evidence for effects on learning ability, many of the contradictions in the literature may be due to litter and strain differences, but it seems that no typical effect can be demonstrated. Many of the learning tasks investigated have been of an aversive or avoidance nature and improvements in learning may well be simply secondary to changes in emotionality (Denenberg, 1964).

The last category of effect - that of an altered stress response - is in some ways difficult to assess behaviourally as the response, such as consummatory behaviour, of an adult handled animal, in a stressful situation may be an exhibition of different reactivity or emotionality rather than a differential response to stress resistence, (see Levine, 1957). Physiological measures have shown early handling to influence the subsequent behaviour of the rats' adrenal system, the handling itself provokes an adrenal stress response (Denenberg et al, 1967), the maturation of the stress response is accelerated (Levine et al, 1958) and adrenal responses of adult handled rats to mild stressors show an increased efficiency in that the overall response is shorter and faster than that of a control. The reaction to chronic stressors or resistance to disease, however, seems no more likely to improve as a result of early stimulation than to worsen.

(b) The question of whether these effects of infantile stimulation can really be considered beneficial arises due to the common error of interpreting experimental results in terms of mans' own experience, even when one is dealing with rats. For any such research to provide benefit for the animal concerned it must allow the animal at least equal or improved adaptiveness to its natural ecological niche. This shows immediately that one must constantly bear in mind species differences and that which may benefit one type may be harmful, or disadvantageous, to another.

With regard to the acceleration of development and facilitation of growth, there is no reason to suppose that this could be adaptive or beneficial to the organism - bigger is not necessarily better. As King (1968) has stated "....If an adaptive response can be enhanced by the acceleration of its development....such acceleration is likely to occur", but there is no evidence that the normal laboratory animal is necessarily retarded in its development as compared with a wild equivalent.

Most of the arguments in interpretation towards a beneficial influence of early stimulation imply that an animal exhibiting a fear response in a 'novel but not physically threatening' situation such as the open-field (Levine and Mullins, 1968) is an emotionally unstable (Hall and Whiteman, 1951) or disturbed (Denenberg, 1963) individual. These researchers are not looking at the situation from the point of view of the animal - when one considers that most of the animals used in this form of research are small rodents that are naturally preyed upon in the wild, it is highly unlikely that a reduction in emotionality (and hence natural caution in novel situations) can do anything but harm. For such an organism exhibition of extreme wariness is highly adaptive, as Daly (1973) states '...It should be obvious that any small rodent who unhesitantly enters a brightly lit, novel environment is pathologically fearless'. More recently it has been accepted that such behaviour as freezing is a natural adaptive behaviour but the above interpretation is still more conventional.

Changes in learning ability are clearly most likely to give benefit and one could argue that, together with a reduced fear of novelty, which would enable the animal to experience greater exploration and hence exploitation of the environment, (Denenberg 1968, 1969), these could put the animal at a greater advantage in an environment. As this is the only real benefit of these effects - and, itself, is open to interpretation - the idea that handling bestows advantages upon the animal is untenable. The misinterpretation of these 'advantages' has been attributed by Daly to an anthropocentric research orientation which has led to the notions of maladaptive emotional responses, 'impoverished' laboratory environments and an increasing tendency to generalise excessively. A cautionary quotation illustrates this unfortunate situation....'If we cannot generalise across strains within species (particularly, for example, with mice), it becomes very questionable to generalise across species, and, personally, I am a bit disturbed by the increasing number of references to very limited animal studies in child-development textbooks and to the implications that are sometimes drawn from this research'(i.e. early stimulation) (Henderson, 1969, cited by Daly 1973).

I do not intend this to mean that there can be no interplay of ideas between animal studies and research with reference to man. Indeed, it seems that man may well respond to early stimulation in ways that may appear similar - for example; premature babies which are swaddled and given a lot of personal attention from the nurses appear to have a better survival rate than those kept in incubators (Ambrose, 1969, page 97-105), handling increases growth and motor development in low birth weight infants (Solkoff et al, 1969), the practice of certain primitive tribes to stress their young (supposedly traditionally to ensure good growth and ability) results in increased growth (Landauer and Whiting, 1964); the usefulness of nursery or playschools for young children may be in that the extra stimulation provided produces less timidity and hence greater ability in them as in rats. The use of extra stimulation over and above the normal threshold in an attempt to habilitate certain brain damaged children appears to produce positive results. It seems that what is lacking in the interpretation of many of the experimental results obtained is a basic biological understanding of the animals used as subjects in this form of research. Animals are not simply 'black boxes' for the benefit of experimental psychologists, but respond variably and adaptively within a given situation. Species differences are also valuable in understanding the shaping by evolution of each species' individual behavioural repertoire to deal with its own ecological niche, for example, see Dilger (1962) who demonstrated this by studying the behavioural differences between the nine species of lovebirds.

(c) Lastly, what function do these effects serve in the context of the animals' lifestyle - or is it just an interesting 'syndrome' that may be produced within the research laboratory. A generally accepted theory proposed by, amongst others, Levine (1962b), is that infantile stimulation equates the laboratory situation more nearly to the natural environment. The argument put forward is that preweaning stimulation provides sudden and drastic changes within the environment as might be expected in the natural situation. Implicit within this explanation is the assumption that all the effects are beneficial and therefore one might intimate that the situation was more normal, as the natural environment would be expected to produce the most adaptive animal. The question that immediately arises from this theory is - is the natural environment of a preweaning rat (or most other rodents for that matter) really subject to 'sudden and drastic' change as suggested. This implies that the normal laboratory environment is impoverished, which gives support to the view that the handling effects would be beneficial.

It is known, however, that the animals used for research in this field tend to be animals that rear their young in burrows (see Lore and Flannelly, 1977 for rats; Hayward, 1965; Stanley, 1971; Alcorn, 1940 and Ewer, 1967 for other examples) - indeed, one of the responses to pregnancy in these rodents is an increase in digging (Calhoun, 1962). It is unfortunate that little field research has been carried out specifically on the typical species used for study but the use, and attachment to, nest sites is so widespread amongst this type of animal that it is likely to be true in all cases. It is also extremely rare for these infant rodents to be found outside their burrows until well after weaning (see Rowell, 1961a for the golden hamster) as found by most field workers. We must therefore examine the two environments - burrow and laboratory - to determine their similarities and differences, and their relative levels of stimulation for the neonate.

The typical burrow is virtually without light and any sounds from outside would be greatly attenuated, indeed, breeding burrows are often found to be particularly deep and well buffered from the outside world (see below).

With relation to temperature conditions and humidity levels these are known to be extremely constant and the temperature of the burrow may often be maintained as high as 30 degrees C, particularly during the breeding season. Even if a particular species lives within a colony it is common for the pregnant female to establish her own nest site where she will have little interference from other members of the colony. The evidence therefore points to a very constant, warm and quiet environment which may be described as a 'postnatal womb'. The laboratory environment, by comparison, exposes the neonate to light on a 24 hour schedule; sounds, often extremely loud, from various sources including both the animals' own and other species'; odours (those of conspecifics having been shown to often exert strong influences on other animals within their sphere) again from various sources; and a temperature typically below that of the burrow although fairly constant. For the neonate, then, the laboratory can only be described as overstimulative and many of the modalities in which the two environments differ have been shown to be effective in producing handling effects themselves (i.e. visual and aural stimulation, and hypothermia during maternal absences).

However, what may be considered an overstimulative environment, as compared with the natural surrounding, for the neonate may be said to become an impoverished environment for that same animal post-weaning. In the normal course of events this change in the perception of the environment would be a gradual one as the young animal's locomotory ability improves, together with its decreasing dependence on the mother for nourishment. These would both lead the animal to leave the burrow and explore its surrounding environment at will. The animal may then well encounter 'sudden and drastic' changes which are totally lacking in the laboratory. Experimental evidence on the differential effects of preweaning and postweaning stimulation lends weight to this theoretical position. That is, the early preweaning environment is responsible for "priming" the animal in its future responsiveness (see Essman, 1971) whilst postweaning experience is more involved with specific learning capacities and responsiveness (see Denenberg, Woodcock and Rosenberg, 1968).

One of the theories put forward in this research, then, is concerned with the effects produced by subjecting a species, in this case the golden hamster, to both a quiet early environment and an enriched postweaning environment as compared with the laboratory rearing situation. Together with the effects of handling the results may be assessed in the light of the above hypothesis that the preweaning laboratory environment is overstimulative and the postweaning laboratory impoverished for a young rodent. The use of the golden hamster as the experimental animal will hopefully provide data towards understanding how general the effects of early experience are.

III. THE GOLDEN HAMSTER

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Mesocricetus auratus (Waterhouse), or Grandfather Saddlebags, as it is known in Arabia, has become widely known since the first specimens were brought into this country in 1931, despite an almost total lack of knowledge of its natural history. Interest now appears to be increasing, due to its unusual sexual dimorphism and related physiology which affects a wide range of behaviours, in the hope of elucidating many of the paradoxes which appear in the literature.
This chapter catalogues the known literature on the golden hamster in order to establish the background against which the research was carried out, because the hamster is much less familiar than the laboratory rat as an experimental animal.

The golden hamster was originally described by Waterhouse in 1839 from an examination of a preserved female and a skin with skull. He designated it as a separate species as it differed from the common hamster on three points - its smaller size, shorter tail, and greater number of nipples. Despite four further reports little definite was concluded about its lifestyle or place in scientific classification - in 1884 Tristram reported that he '...frequently saw a light-coloured hamster among the bushes and wild plants (in Palestine) but was unable to obtain any specimens', and it was not until 1932 that the first full description of the species was given, by Aharoni from evidence off the first litter to be found in the wild.

This litter was found in April, 1930, near Aleppo in Syria, in a burrow eight foot deep, and consisted of a female and her young - quoted as a female and twelve pups (Bruce and Hindle, 1934; Walker, 1968) or a female and eight pups (Adler, 1948). The animals were taken to the Department of Parasitology, Hebrew University, Jerusalem, where they were used by Adler to study kala azar, a tropical disease. Prior to this Chinese hamsters had been used but the new-found golden hamster had a great advantage - it bred readily in captivity. A stock was built up from one male and two females from the original litter and in 1931 two pairs were brought to England by Dr. Adler and presented to Dr. Hindle. These were used to build up a stock at Glasgow University, from whence all hamsters known today in England and the United States, where they were first taken in 1938, have originated.

It was assumed that these animals must have become extinct over the past century, hence the rare sightings, and although there was some advantage for research in having such a confined gene pool the artificiality of the population seems overwhelming.

It is probably for this reason that hamsters are used far more widely in medical research, where a ready supply of living animals is the necessary requirement, rather than psychological research, where an understanding of the organisms natural lifestyle, social structure and mode of behaviour is more important. However, this view has been shattered by a report by Murphy (1971) that golden hamsters exist in fairly plentiful numbers around Aleppo - to the extent of being regarded as agricultural pests by farmers. It seems astonishing that this should be so, after years of literature statements that only one litter had ever been found - one wonders how closely they looked.

Pending the initiation of an adequate field study, what is known of their natural habitat is as follows - The golden hamster has a very restricted geographical distribution only having been recorded around Aleppo, in north-west Syria, although possibly extending into the West Bank, Jordan, Iraq and the Turkish plateaus. It leads a solitary, nocturnal existence in extensive burrow systems of its own making on brushy slopes, partly vegetated slopes and in grain fields. Its major source of diet is wheat, which it hoards in its burrows, although in captivity is almost omniverous eating many kinds of green vegetation, seeds, fruit and meat. The climatic conditions of its natural habitat are such that fresh vegetation is only available during fall and winter when there is increased rainfall and lower temperatures - a factor which probably influenced its evolution as a hoarder. As already mentioned the golden hamster is a very solitary animal and readily fights conspecifics - although it is possible that families, though not living together, will live in close quarters within the burrow system. Both this question and that concerning the extent of their territorialism must wait for further study in a natural surrounding. Their main predators are the owl, jackal, snake and man; and Murphy reports that their existence is now being threatened by agricultural mechanisation and irrigation.

General references on this species include;-

Bruce and Hindle, 1934
Encyclopedia Britannica
Walker 'Mammals of the World' 1968
Hoffman, Robinson and Magalhaes, 1968

A single attempt (Howard, 1959) has been made to study their survival in the wild when 37 subjects were released in large rodent-proof pens in Californian rangeland. Only one male survived longer than seven weeks - probably due to the lack of suitable food and cover - and this compared favourably with several native species. No record of behaviour was made at this time as the object of the study was simply an establishment of a feral population - which appears quite possible under suitable conditions.

The speciation originated in the Caucasus and radiated into three major groups - in the east the Chinese hamster, in the west the European and in the south the Syrian or golden hamster. The golden hamster has a chromosome number almost double that of the other two species - leading to the hypothesis that it arose via polyploidy (that is, it is amphidiploid from two other surviving species). As well as the evidence from the chromosome number there is some slight evidence from some hibernation studies (Chaffee, 1966) in which it was found that some animals readily hibernate whilst others will not. From these one may breed either pure hibernating or non-hibernating stock which also differ in certain physiological measures. This genetic evidence led to two main views which explained the rare sightings of this animal - (i) either it arose purely by chance now and again from two existing species, or (ii) it was an evolutionary experiment which was not suited to its environment and could not maintain. However, as these views were based on the assumption the animal was rare and all but extinct they seem rather obsolete in view of the claim these animals are in fact so common as to be regarded as pests. A suggestion by Richards (1966a) that this was a recent evolutionary species, still possibly in a rather rudimentary form, seems more satisfactory.

In a study of maternal behaviour it was found that pups elicited the maximum maternal behaviour from the female when they were about six days old. This is contrary to evidence from, for example, mice where the younger the pup the more maternal behaviour it elicits. It seems likely then, that the golden hamster has only recently reduced its gestation period from the ancestral 20-21 days, as shown by both the European and Chinese species, to 16 days, the shortest known period for a mammal - but that the behaviour of the female has not yet 'caught up' with this short gestation.

It is significant that reports of cannibalism by the female suggest that it occurs within the first six days after the litter is born (see Daly, 1976; Scott, 1970). This reduction in gestation could have been an evolutionary advantage in that it increased reproductive potential in an area of irregular food and rain supply. If this were true the mechanisms in the reproductive behaviour of hamsters could be very unusual and particular care must be taken when making cross-species comparisons.

Development

Both the prenatal and postnatal physiological development of the golden hamster have been well-documented. No attempt will be made to cover it all here since reference to Hoffman, Robinson and Magalhaes (1968) will supply a complete picture of the embryological development of this species, and Scott (1970) provides a detailed study of its postnatal development. A summary of certain relevant details is given below; and the development of behavioural repertoires is also given in tabular form (see tables 1 - 4). A discussion of their importance in relation to comparable species occurs later in the text.

Social Behaviour

Just as little is known of the hamsters social structure in its natural habitat, so little research has been carried out into its social behaviours - the main categories of study being maternal and agonistic behaviours.

1. MATERNAL BEHAVIOUR

A complete description of these behaviours may be found in Daly (1971). Nestbuilding increases steadily during pregnancy from the normal level, and this high level of nest maintenance is maintained for at least the first two weeks postpartum when it declines, reaching the normal level again about the 30th day postpartum. There is also a general improvement in the type of nest built - often a deep nest with thick well-formed high walls and at least a partial, occasionally complete, covering of the litter (Scott, 1970). When the litter is two weeks old their homiothermic capacity is developing and the female begins to lose interest in nestbuilding which appears to be controlled by the temperature of the pups to which she is very sensitive.

TABLE 1: Behavioural Development in the golden hamster

Age		Source
Birth, Day 0-1	Very limited movement - amplitude limb movements very small, show unique 'swimming' motion on back; lie on backs in nest; little movement; suckle; thermotropic; nipple-seeking.	Daly (1976) Daly (1971)
2	Yawning	Daly (1976)
3	Orientate to centre of nest, prefer belly or side-down posture, right themselves if tipped.	Daly (1976)
4	Classifiable movements begin - e.g. forepaw grooming	Daly (1976)
5	Self-righting	Daly (1976)
5-6	Start eating coecotrophia produced by female.	Scott (1970) Daly (1971)
6	Start using pouches as stores	Scott (1970)
7	Scratch with hindfoot	Daly (1976)
8	Eat hard food	Waterman (1948) Daly (1971), Scott (1970)
8.5	Contactless scratching, mouth food	Daly (1976)
9	Locomote with head supported	Daly (1971)
8-10	Start to eat normal faeces	Daly (1976) Dieterlen (1959)
10	Pups begin foraging in food stores in nest.	Scott, (1970)
10	Begin eating	Daly (1976)
10	Independent urination	Dieterlen, (1959)
10.5	Snout grooming	Dieterlen, (1959)
11	Leave nest for first time to locate food and water	Scott (1970)
	True walking appears	Daly (1971)
	Cheekpouch emptying	Daly (1976)
	Independent defecation	Daly (1976)
11-12	Head scratching	Daly (1971) Dieterlen (1959)
11.5	Eat sitting up	Daly (1976)
	Exit from nest	

Age		Source
Day 12	Pups capable of grooming, feeding, using urinating spot, removal own faeces (16 days - Dieterlen) from nest. Begin to resist females attempts at retrieval.	Scott (1970)
	Scratch with contact	Daly (1976)
	Independent urination	Daly (1971)
	Scratch with foot-licks; overhead grooming	Daly (1976)
13	Locomotive skills - good support of body, control, steadiness and speed.	Scott (1970)
	Begin to groom with mouth	Daly (1971)
	Social behaviours begin between littermates	
13.5	Chew nest material	Daly (1976)
14-16	Forepaw digging	Daly (1971)
14	Independent urination, carry food to nest, swat playfights, shares and swaps food with littermates.	Daly (1976) Daly (1971)
15-18	Pups spend much longer off nest, form groups outside nest, eat from food pile, carry food in pouches to nest and also carry bedding to nest.	Scott (1970)
15	Fighting posture	Daly (1971) Dieterlen (1959)
	Body grooming, forepaw digging	Daly (1976)
15-16	Nest care	Daly (1971) Dieterlen (1959)
16	Playfighting (full)	Daly (1976) Lawlor (1959)
17	Complete digging AP seen	Daly (1971)
	Rearing on hindlegs	Daly (1976)
18	Greatly improved motorability great increase in variety movements. Hyperactive, adult periodicity not yet apparent. Development of form discrimination (i.e. visual sense increasing in importance)	Scott (1970)
	Nest-building ability develops	Daly (1976)

Age		Source
Day 18.5	Mature yawning/stretching AP develops	Daly (1976)
19	Climbing, shaking, hopping & jumping	Daly (1976)
19.5	Complete digging AP seen - i.e. digging with hindkicks	Daly (1975) and (1971)
20	Definite depth perception	Schiffman (1971)
21	Lateral scent-marking occurs	Daly (1976)
	Sniffing at lateral gland	Daly (1971)
28	Hoarding truly seen and complete nest-building. (weaned and isolated - adult threat postures seen)	Daly (1976)
30	Mature scent-marking (depends on both maturation gland and of behaviour AP to appear - therefore, very variable depending on observer).	Dieterlen (1959)
35	Sexually mature with complete adult behavioural repertoire.	Daly,(1971)
42	Males sexually active (marking)	Goldman & Swanson (1975)
49	Females sexually active	
	Fighting beginning	

TABLE 2: Physical development in the golden hamster

Age		Source
Birth	Teeth present	Waterman (1948)
	Completely poikilothermic	Hissa & Lagerspetz (1964)
	Completely naked with bright red somewhat transparent skin through which organs and milk in stomach may be seen. Ear tags fixed back against head, fingers and toes connected by skin. Completely dependent on female for milk diet. Tactile, thermal, olfactory senses present.	Scott (1970)
Day 1	Pale pink due to thickening of skin, dorsal surface somewhat darker.	Scott (1970)
3	Ear tags separate from head; dorsal surface dusty grey colour due to developing hair follicles; flank glands apparent as whitish patches.	Scott (1970)
5	Dorsal surface dark grey with fine hairs	Scott (1970)
5-6	Diet supplemented by special (coecotrophia) soft faeces from female (eaten until day 10)	Scott (1970) Daly (1971)
8	Begins to eat solid food	Scott (1970) Waterman (1948) Daly (1971)
	Gradual loss of thermotactic ability begins	Leonard (1974)
	Dorsal surface highly polished slate black	Scott (1970)
	Eyes begin to open	Scott (1970)
10	Pups lose ectothermism (i.e. beginning of temperature-regulating establishment) - development ,homiothermism.	Leonard (1974)
	Increased basal heat production onset and intensity; shivering response matures.	Hissa et al. (1964)
	Coat has shaggy appearance and is pale beige; brought about by development of guard hairs first.	Scott (1970)
12-14	Hearing develops	Scott (1970)

Age		Source
Day 14-15	Eyes open	Waterman (1948) Daly (1976)
	Rapid fur growth begins	Scott (1970)
16-18	Eyes open	Schiffman (1971)
21	Fur growth resembles adult but without shininess of fur	Scott (1970)
Week 6-8	Develops adult gold colour and shininess of fur.	Scott (1970)

TABLE 3: Physiological development in the golden hamster (embryological)

Age		Source
Days 0-9	Early embryological development	Waterman, (1948) Hoffman et al, (1968)
7-8	Head forming, some development gut and blood Heart and eye development begins	Boyer (1953)
9	Very fast development begins (end of embryonic period)	Graves (1945) Spector (1956)
10	Genital ridge visible	Waterman (1948)
	Anterior limb buds formed	Waterman (1948)
12	(Male gonads) testes develop	Waterman (1948)
13	(Female gonads) ovaries develop	Waterman (1948)
12.5	Active adrenal cortical secretion begins	Hillman & Seliger (1975)
13.5	Metamorphosis ends (sic)	Spector (1956)
15	Hair follicles prominent	Boyer (1953)
Immediately prenatal		
	Genital folds fused Cerebral hemisphere formed Cerebellar rudiment thickened and folded Large olfactory lobes Numerous nuclei and fiber bundles throughout brain stem.	Boyer (1953)
16	Birth	

TABLE 4: Physiological development in the golden hamster (postnatal)

Age		Source
Birth	Physiologically immature; hypothalamus very immature; No ECOG; brain cortex very immature and undefined; densely packed neurons.	Auer (1951) Callison *et al.* (1973)
Day 1	Gradual lamination cortical tissue begins, and dispersion neurons.	Callison *et al.* (1973)
	Neuroblasts of parietal cortex formed from deeper laminae of cortex; neuroblast production coming to an end though none yet in final differentiated form. Structure cortex layered though *not* in adult pattern: lumen neuroepithelium (still some mitosis) subependymal (DNA synthesis and cell division occuring) migratory zone (forms parietal white matter) inner zone (not yet very developed) outer zone thin fibrous zone	Shimada & Langman (1970)
2	Discontinuous ECOG activity begins	Callison, Himwich & Turner (1973)
3	Neuroblasts migrate from periventricular region to surface of parietal cortex.	Shimada & Langman (1970)
5	Sustained cortical activity, low amp.; rapidly differentiating pyramidal cells in brain.	Shimada & Langman (1970)
	Neuroblasts well developed and migrated to surface of cerebral cortex.	Shimada & Langman (1970)
	Hypothalamic cell multiplication (particularly in ependymal layer) ceases	Auer (1951)
Week 1	Adrenal: 2 zones glomerulose and fasciculata	Zieger, Lux & Kubatsch (1974)
Day 7	Amount of fast ECG activity increases with higher amplitudes.	

Age		Source
Day 9	Neuroblasts have differentiated rapidly and formed large mature neurons.	Shimada *et al*. (1970)
10	First displays of all mature ECG components (amp. 20-100 µV).	Callison *et al*.(1973)
	Basilar dendrites develop few collateral processes; apical dendrites thicken.	Callison *et al*.(1973)
	Huge bi-lobed thymus formed, also parathyroids. Adrenals well-organised (epithelial cords and islets of chromaffin tissue), permanent cortex forming. Pineal much reduced in size.	Boyer (1953)
	Hypothalamic median and bilateral nuclei described, i.e. differentiation and migration complete (some by about 5 days).	Auer (1951)
Week 2	Adrenal: medullary cells distinctly visible	Zieger *et al*. (1974).
	Both cortical hemispheres synchronous ECG activity ≡ adult though fast activity still increasing to adult level.	Callison *et al*.(1973)
Week 3	Thickening and branching, apical dendrites already developed.	Callison *et al*. (1973)
Week 4	Adrenal: dark and light cells (mainly at cortico-med. junction)	Zieger *et al*.(1974)
	Neuronal density and ramifications brain cortex ≡ adult	Callison *et al*.(1973)
Day 30	3 main zones distinguished in adrenal cortex.	Hoffman *et al*, (1968)
Week 5	Significant and lasting differences shown in male and female adrenals (mainly due to differences in reticularis cells, small in female, large in male).	Zieger *et al*. (1974)
	Maximum myelination caudal hypothalamus attained and temperature regulation ability established.	Buchanan & Hill (1949)
	Onset of oestrus cycles in females	Waterman (1948)
Week 6-7	ECG activity ≡ adult (amp 50-150 µV)	Callison *et al*.(1973)

There is an effect here of litter size - namely, the larger the litter the faster the decline in the females attachment to the nest. It is also around this time that the pups are gaining independence from the female (see developmental data above).

An excellent paper by Rowell (1961a) describes this break-up of the family group. Between the second and third week postpartum the female stops retrieving the young, begins to wean them, and stops rebuilding the old nest - indeed she may well build a smaller one elsewhere. Possibly in the natural situation she would leave the litter at this point. During the fifth week, the pups finally stop attempting to suckle and to show contact behaviour; they begin to form small groups on their own, make frequent escape attempts and may occasionally be attacked by the female. This would seem to be the natural dispersal stage of the family.

The position of the male in this group is in question. It seemed likely that his presence was actively prevented by the female (Yaron, Chovers, Locker and Groen, 1963; Eibl-Eibesfeld, 1953) but there have now been several successful attempts at keeping breeding pairs together (see, for example, Marques and Valenstein, 1977) and the participation of the male in litter care may have survival value as has been shown for other rodents maintained in pairs (Dudley, 1974; Elwood, 1977). The response of adult hamsters to pups has been well-studied and males will readily carry and nurse young pups; the males also show less cannibalism than the females, with even pregnant females often attacking pups (Rowell, 1961b; Richards, 1966b; Scott, 1970). These results have been explained using the females known greater aggressivity and territorialism - however, no correlations have been found between levels of aggression in females and their responses to pups; although gonadal hormones, in particular progesterone which is known to increase aggression, do play some part in the control of this behaviour (Marques and Valenstein, 1976). In a colony situation the females aggressive behaviour during pregnancy appears territorial and once a litter is born this aggression is solely used for the defense of the young and nest site (Frey, 1966).

2. AGGRESSIVE BEHAVIOUR

The establishment of dominance relationships in golden hamsters has been shown to be a very simple arrangement based on aggression (Boice, Hughes and Cobb, 1969). Stable rank orders were established in water competition rankings and these positively correlated with body weight, overt aggression and tunnel competition dominance. A further study on these predictors of dominance was conducted by Drickamer et al (1973a, 1973b) which showed that in males the outcome of a social interaction was significantly related to body weight and to the size and pigmentation of the flank gland. It is the state of this flank gland, which is related to endogenous androgen levels, which is the true predictor of social rank. Despite the smaller, less-pigmented flank glands in the female this relationship still holds true; with body weight again closely related. However, the fluctuations in aggressive behaviour associated with the oestrus cycle do not correspond to fluctuations in dominance so it seems unlikely that aggression is the only factor in the establishment of social order.

Indeed, a study by Lawlor (1962) suggests that one must pay greater attention to the range of behaviours, other than aggression, which are involved in the expression and maintenance of dominance relationships. The important difference of her study is in using littermates, caged together from birth, within a social group rather than strange animals where obviously overt aggression, as an exmperimental artifact, may well be expected. (This has already been shown with mice (see Urich, (1938) who used cage groups and Scott (1948) who used the typical round-robin technique).) In this case, it was found that dominance was correlated with activity, inter-animal contact behaviours such as ousting, stepping-on and barging-into and also escape from a 'paper-box'. These measures, however, do not correlate with either biting behaviour, competition in a runway test, nor body weight. These measures were related to a qualitative 'type' for both dominant and submissive animals.

It seems likely, then, that in studies of dominance one must pay attention to the integration of behaviour processes within the total life pattern of the species, whilst aggression may be studied in predictable and variable experimental situations.

The IRM for aggression in this species in the black marking on the chest which is displayed in the adult aggressive postures (Grant, Mackintosh and Lerwill, 1970), intensification of which produces increased flight behaviour in the attacked animal. If paired animals, one with dyed chest patch, are caged together the animal with the supranormal threat stimulus quickly becomes dominant and more aggressive, and has a much greater growth rate (Payne and Swanson, 1972a).

Although Drickamer attributed dominance order, and by correlation aggressive levels, to the level of testosterone circulating in the animal, Swanson (1971) showed that in the female aggression and dominance were controlled by progesterone. Both sexes showed pronounced fighting behaviour but the intact, sexually unreceptive female is normally dominant over, and more intense in fighting than, the male (Payne and Swanson, 1970; Lerwill, 1968). Wise (1974) also attributed aggression of the female towards the male to levels of female hormones, in this case prolactin, due to the increase found in pregnant and lactating females compared with normally cycling females. Whether these changes in aggression were due to an hormonal effect on the females' behaviour or to changes in the males' behaviour via olfactory cues is not yet certain.

The control of aggressive behaviour by sex hormones is definitely implicated by a number of studies by Payne and Swanson (1971a,b,c; 1972b,c) and Payne (1973) which show: castration leads to a reduction in the amount of aggression directed towards both sexes, which may be restored by androgen replacement therapy and ovarian implantation; spaying also leads to a reduction in aggression but the aggressive behaviour is only restored by progesterone and not testosterone treatment; an intact male treated with progesterone will show increased aggression towards the female, whereas treatment with testosterone increases aggression towards the male. Evans and Brain (1974) found that the effects with the male were due to a decrease in the 'attackability' of the animal when castrated, which was then increased again by testosterone treatment. Progesterone treatment of a castrate has also been shown to influence, by decreasing, the level of aggression in the opponent. However, ovariectomy does not lead to any alteration in the attackability of the subject.

It seems likely then that progesterone controls the levels of aggression shown by a direct hormonal action, whilst testosterone controls the attackability of the subject in an encounter, via olfactory cues. This possibility may explain the great increase in aggression shown by males in stressful situations (see Goldman and Swanson, 1975) as there is a definite link between adrenal responses and testosterone levels (Gaskin and Kitay, 1970, 1971; see also Brain and Evans, 1972). Further support for this possibility is that in pairs of golden hamsters it is the female that determines the presence or absence of aggressive behaviour (Marques and Valenstein, 1977). However, Payne (1973) demonstrated that increased aggression occurs in males due to increased androgen secretion, as would occur in stressful conditions.

3. SEXUAL BEHAVIOUR

Although the sexual behaviour of golden hamsters has been fairly extensively covered it is with a physiological, rather than a behavioural, approach - probably due to the interesting physiological aspects afforded by the sexual dimorphism of this species. The development of sexual behaviour has been described by Rabedeau (1963) although this may be dramatically altered by neonatal intervention in the form of hormonal administration or gonadectomy. Such intervention affects both sexual behaviours and behaviours controlled by sex, such as open-field activity - for example, Payne (1979a) has demonstrated neonatal females treated with androgens exhibit 'defeminised' adult sexual behaviour together with an increased likelihood to demonstrate male sexual behaviour. These effects are invariably enhanced by the additional treatment of hormones when adult (see also Johnson, 1975). These findings compliment those of Swanson (1966, 1967) for both androgen and oestrogen treatment in 2-day old females leading to an exhibition of male open-field behaviour, although gonadectomy was less effective. Many of the results of gonadectomy in this species, such as the loss of adrenal gland dimorphism and increased weight gain in the male demonstrate the important activating role of the androgenic hormones rather than the ovarian steroids in this species (Gaskin and Kitay, 1970; Wade, 1968).

For mechanisms regulating sexual behaviour in this species and on the effects of hormones, such as progesterone, the reader is referred to Lisk (1970), Lott (1962), Johnson W.(1974) Braun (1953) and Krehbiel (1952).

Levels of activity in the female, together with changes in exploration and distractability, are well-related to hormonal changes as a result of the oestrus cycle (Richards, 1966c; Birke, 1976). No effects on mating behaviour are found in the male as a result of removal of seminal vesicles, prostate or testes (Pauker, 1948). The fact that oestrus female Turkish hamsters (Mesocricetus brandti) can avoid copulation with non-preferred (i.e. Syrian rather than Turkish) males has been accepted as support for the possibility that sexual preferences may serve as a species isolating mechanism in hamsters (Murphy, 1978).

The importance of olfaction in mediating sexual behaviour is well-documented in many species and has also been shown to have importance in this species. However, from studying the literature it appears that olfactory cues are simply initiators of contact and that behavioural cues are more important in the mediation of sexual behaviour. Support for this comes from the finding that whilst olfactory blockade (Devor and Murphy, 1973) or bulbectomy (Winans and Powers, 1974) can affect male golden hamsters it does not prevent them from displaying normal sexual behaviour.

It has been demonstrated that the vaginal secretion of the female is attractive to the male (Johnston and Lee, 1976) although neither naive nor sexually-experienced males appear to discriminate between receptive and non-receptive females (Landauer, Banks and Carter, 1978); although an experienced male does attempt more mounting. The fact that vaginal marking occurs maximally in the presence of males and on the eve of oestrus suggests it has a 'sexual advertisement' function as opposed to the flank-marking behaviour which has a territorial role, possibly related to aggressivity (Johnston, 1977). The failure of males to differentiate between samples of Harderian gland smears from receptive and non-receptive females (Payne, 1979b) supports this claim that male hamsters find female olfactory cues generally attractive, unlike many other mammals (rat, dog, monkey) where the male responds differentially to a receptive female. Studies by Steel (1979, 1980) demonstrate that changes in female behaviour, such as approach to a male, vary over the oestrus cycle as a result of the hormonal changes occurring (see also Goldman and Sheridan, 1974), and that these changes result in behavioural cues which regulate male/female interaction.

4. SOCIAL BEHAVIOURS AND USE OF SPACE

The golden hamster exhibits a wide range of natural behaviours in the laboratory and maintains its cage in a constant arrangement showing both spatial and temporal organisation of behaviour (Johnson, R. 1974) A specific sleeping spot is maintained at which most eating and grooming occurs, although there may be another regularly used feeding site. Urination always occurs at a specific spot away from the sleeping area, although faeces elimination occurs both throughout the cage and at eating places. The cage is constantly marked and vigorously defended if intruded upon (Murphy, 1970), whilst introduction to anothers cage results in a great increase in digging resulting in total disarray.

All the social postures displayed by other laboratory rodents are commonly displayed (Grant and Mackintosh, 1963) although their spatial organisation is species specific. In an encounter between male pairs in a neutral environment (Gerritz, 1971) the animals spent only 20% of their time in mutual physical contact whilst removal of one of the pair had no effect on the others emotionality or mobility.

Social behaviours within groups of any size are dependent on the area and shape of the space available to that group - for example, in small areas one gets a greater amount of biting which decreases rapidly with larger areas whilst ousting behaviours increase slightly (Lawlor, 1963). Shape, whether square or circular, is even more important due to the preference for corners. The effects of environmental size, complexity and confinement on the temporal trends of escape and exploratory behaviours are discussed by Johnston (1964).

General Physiology

In general structure the hamster resembles other common laboratory rodents excepting that its digestive and excretory/eliminative systems are those typical of desert species and aestivators, in that they are adapted for water conservation.

With regard to the hamsters sense organs the primary sense of perception, as would be expected for this type of nocturnal species, is olfaction and any loss of this function results in an alteration in typical maintenance behaviours (Goodman and Firestone, 1973) although rearing in olfactory isolation does not affect olfactorily related or sexual behaviours (Dieterlen, 1959).

Sexual maturity of this species is reached very early by 5-8 weeks. Although there is no distinct breeding season there is a marked decrease in fertility during the winter months. The reproductive ability is under both environmental and genetic control varying with season. This variation seems controlled via the pineal (Hoffman, Hester and Towns, 1965; Hoffman and Reiter, 1965) which responds to the length of photoperiods, with the visual system providing some mediating influence. The results are a seasonal variation in the size of the testes, variations in the pituitary prolactin levels (Kirby, 1963) and an alteration in the oestrus cycle with low light levels. In the male sexual activity is maintained even after castration via the secretion of androgens from the adrenal gland (Pauker, 1948).

An interesting feature of the hamster is that it is remarkably free of disease and has a great immunological tolerance. This has led to a unique use in research due to the atypical immunogenetical characteristics of the species. It is widely used in medical research for the following reasons: having few spontaneous diseases (apart from wet-tail); good sensitivity to viruses for virology research; immunological tolerance leads to use in tissue and cell transplantation; very useful in dental research; microcirculation techniques due to accessibility of its blood vessels in the cheek pouches. However, it does seem to have a high degree of spontaneous tumours and cancers, especially adrenocortical hyperplasias and adenomas (Fortner, 1958). It is difficult to draw conclusions from this high incidence although only two surveys have denied its existence (Chesterman, 1962; Schubik _et al_, 1962).

It seems likely, however, that, as with mice, there are great strain differences in this phenomenon. Fortner et al (1961) was led to conclude this species to be 'endocrinologically aberrant', an alternative suggestion being that the tissues are abnormally sensitive to endocrine stimulation, which may be a result of stress (Hoffman, et al, 1968).

The pineal is closely associated with reproductive functions, regulating them to be compatable with changing environmental conditions. Short photoperiods activate the gland to inhibit gonadal function (in the males at least this causes the hypothalamo-hypophyseal neuroendocrine system which controls gonadotrophin release to become relatively insensitive to gonadal steroid hormone feedback). This does not occur in pinealectomised animals and it seems likely that in its natural environment the golden hamster is a seasonal breeder and hibernator (Hoffman et al, 1965).

The pineal is also involved in thermoregulatory mechanisms (Heldmaier and Hoffman, 1974) and thought to have interrelations with the zona glomerulosa of the adrenal cortex. The gland has its maximum volume, and therefore its probable maximum activity, when there is low activity in the other endocrine glands.

In the adrenal gland the medulla is similar to other species but the cortex, although structurally and histologically typical of other rodents and eutherian species, has certain important variations (Peczenik, 1942a; Koneff, Simpson and Evans, 1946; Keyes, 1949; Bourne, 1949; Alpert, 1950; Holmes, 1955b). The major differences from other laboratory rodents are in the histochemical nature of the cortex (for more detailed adrenal physiology see below). The hamster possesses a 'lipid-poor' adrenal which has only small or negligible amounts of cholesterol compared with the large amounts of cholesterol and other lipids (such as sudanophilic lipids) found in 'lipid-rich' adrenals of such species as men, dogs and rats. The patterns of adrenal ascorbic acid (AAA) depletion are very different from other rodents (see Elton, Zarrow and Zarrow, 1959), and it seems that secretions from the pituitary are not required to maintain the zona glomerulosa as would be expected.

However, with age (and also under the influence of certain stressors such as X-ray irradiation) senescent changes occur which cause an increase in sudanophilia and in the deposition of cholesterol and so giving the gland more of the expected attributes (Sahinen and Soderwall, 1965; Meyers, 1950).

The main adrenal steroid is cortisol, with no production of hydrocortisone. Most laboratory animals (i.e. with lipid-rich adrenals) use cholesterol as a precursor but in the hamster this does not appear to be the case as (i) cold stress (5 degrees C) does not cause accumulation of cholesterol levels as it does in the rat; (ii) certicoid-blocking agents, such as amphenome B, do not cause accumulation of cholesterol or any change in corticoid production. This is supported by the fact that although free cholesterol levels are the same in the hamster and the rat, the rat has at least nine times the amount of esterified cholesterol present than in the hamster (Hoffman _et al_, 1968). There does also not seem to be any storage of steroids in the cortex and that rapid synthesis occurs when required. The hamster has one of the lowest normal secretion rates known (approx. 0.5mg/kg/day) but there can be a wide range of secretion depending upon the living conditions (Schindler and Knigge, 1959a).

Under favourable conditions - such as dim light, short photoperiods, cool temperature, ample food and bedding - golden hamsters will hibernate. As already mentioned, however (see above) this trait is thought to have a genetic basis as one may breed 'hibernating' and 'non-hibernating' stock - the rapidity with which this is obtained indicating the control by only a few genes.(1) The stock so obtained also have differences in endocrine function which amounts to a modification of the hypothalamo-hypophyseal link in the chain of endocrine regulation. This is the major adaptive mechanism making them, in some ways, '...similar to a stalk-sectioned homeotherm' (Hoffman, in Dill, Adolph and Wilber, 1964). For example, instead of the increased thyroid activity associated with cold exposure, one gets a blocking of thyroid activity, primarily due to a direct effect of low temperature on the thyroid gland and a reduced secretion of TSH.

(1) It is of interest to note that within these two populations those males that hibernate all have small testes whilst those that do not have large.

Hibernation also results in a reduction of plasma cortisol levels of 43% which returns to normal within 6 hours of arousal (see Kayser, 1946; Chatfield and Lyman, 1950; Lyman and Chatfield, 1950; Roberts, Mooney and Martin, 1964; Gumma and South, 1970).

Growth in the golden hamster is mainly dependent on nutrition, although also partly on season. Growth is more rapid during autumn and winter than during spring and summer (a point that has been used to support the theory that hamsters are naturally summer aestivators rather than winter hibernators - although it is possibly simply a reflection of the continuous food supply available in the laboratory). It may also be noted that males grow more than females during winter, spring and summer, whilst females grow more than males during autumn.

Physiologically, then, these animals are well-suited to endocrinological research work - especially within the fields of environmental, and age-related studies. They appear to retain seasonal modifications in behaviour (Gumma, South and Allen, 1967), reproductive physiology and endocrine activity which together with their short life span, extremely early pubertal age and short gestation period make them ideal and amenable animals to work with.

Adrenal Physiology and Stress Reactions

As well as being relatively larger in the hamster than any other species, and therefore possibly more important, the adrenal differs in a number of ways than those of other common laboratory rodents. The two basic points to remember are that the sexual dimorphism is reversed in this species, compared with the laboratory rat, and that the adrenals are lipid-poor. Dimorphism is defined as "the occurrence of two forms in the same species (Biol.)" (Chambers Dictionary, 1972 Edition) and sexual dimorphism obviously exists, therefore, in physiology and behaviour directly related to sex characteristics. However, dimorphism may also occur between the sexes in other aspects of their physiology and behaviour -

such as, for instance, general activity levels. In the present context a reversal in sexual dimorphism is said to be demonstrated in the golden hamster in comparison with the rat in that the general 'male' attributes of the rat are exhibited by the female golden hamster. Specifically, these include greater body weight, smaller adrenals and higher levels of aggressive behaviour. Both the above factors (i.e. unusual sexual dimorphism and adrenal physiology for a laboratory rodent) may be attributed to the fact that hamsters are, or at least show the ability to be, hibernators whilst other species normally under study are not.

1. LIPID-POOR ADRENAL

Mammalian adrenals may be divided into two distinct groups, i.e. lipid-poor and lipid-rich, by (i) the size, number and distribution of lipid droplets in the cortical cells and (ii) by the presence or absence of a positive reaction to the Schulz test for cholesterol. The hamster adrenal gives a negative reaction to the Schulz test showing no, or negligible amounts of, cholesterol present (Verne and Herbert, 1951). There are few, if any, lipid droplets observable and the histological staining reactions show those lipids present to be structural rather than metabolic (Marks, Alpert and Kruger, 1958).

The morphological and histophysiological differences in this type of adrenal indicate basic differences in the functional metabolic pathways. Despite contradictory evidence of steroid production in the adrenal cortex of this species (probably caused by taking blood from various sources and also differences arising from in vivo and in vitro studies), the main steroid produced is cortisol with some corticosterone. The normal precursor for these steroids is cholesterol but investigation, using drugs known to affect steroidogenic pathways in lipid-rich adrenal animals, has shown this not to be the case in the hamster. Marks et al (1958) fed males daily with amphenone-B, known to affect steroidogenesis by inhibiting the use of cholesterol, and found no increases in adrenal weight, no increase in cholesterol nor any change in the lipids of their adrenals. They concluded that this species probably synthesises steroids (C_{21}) by condensing short-chain units directly rather than using the much larger chain (C_{27}) cholesterol. This is supported by evidence from Schindler and Knigge (1959b) who concluded the use of cholesterol was dependent upon its permeability within a species. (In vitro studies of cell-free adrenal homogenates readily converted cholesterol to steroid whilst adrenal slices did not). They also showed that adrenal tissue cannot produce steroids therefore demonstrating that there is little storage of steroid precursor within the gland (1959a).

Lloyd (1972) found that there was very rapid synthesis compared with other laboratory rodents, up to fourteen times as much, which he attributed to different regulatory points such as membrane enzymes, transport, etc. Despite this very rapid synthesising ability the hamster also has an extremely low rate of steroid secretion (Schindler and Knigge, 1959a) which varies widely normally - depending, it seems, on housing conditions and other environmental variables, although there are no differences between the sexes.

2. SEXUAL DIMORPHISM

The sexual differences shown start to appear by 30 days of age and by 100 days the adrenal weights plateau. The male gland is both absolutely and relatively heavier with a wider cortex than the female (Peczenik,1942b, 1944) and this difference may be attributed to different structure. The reticularis and fasciculata (the two inner adrenal cortical zones) have larger cells with the appearance of intercellular vacuoles in the male, whilst the female has decreased cell size in the reticularis with no vacuoles and the other cells also tend to be smaller. The increase in size in the male corresponds to release of androgen at puberty although this dimorphism may also be due to the inhibition of ACTH release by progesterone in the female (Snyder and Wyman, 1951); these sexual differences are not apparent if gonadectomy is performed before 30 days. This also results in some adrenal weight loss which may be restored by testosterone (Gaskin and Kitay, 1970), although as yet it is uncertain whether this increases ACTH secretion or has a direct effect on the gland itself, Gonadectomy after puberty also results in a loss of sexual differences, due to an increase in the adrenal weight of the female and a decrease in the male (Peczenik,1942b) - seeming to suggest both female and male hormone influence - a possible indication that aromatisation does occur in this species.

The male gland is also more active with a higher rate of steroid secretion and faster metabolism (Chester Jones, 1955; Zeiger, Lux and Kubatsch, 1974). Gaskin and Kitay (1970) also reported the levels of plasma cortisol to be higher in the male than the female, although there seems to be no correlation between the blood cortisol concentration and the adrenal weight (Denyes and Horwood, 1960).

The sexes also show different responses to stimulation - for example, Wexler (1951) showed a different pattern of adrenal ascorbic acid depletion in response to a single injection of diethylstilbestrol (see below). These different responses may explain in part why the female is more hardy and aggressive than the male - i.e. the female adrenal and/or pituitary is more responsive, therefore allowing the female greater capacity for adaptation and resistance to stress.

3. STRESS REACTIONS

Studies in this field have followed accepted reactions of other species, notably the rat; such as fluctuations in adrenal ascorbic acid, adrenal lipid and cholesterol levels related to ACTH output, and also gross measures of adrenal and body weight, together with histological changes.

i) ACTH:

The direct action of this hormone causes increases in adrenal weight in both immature (slight) and young adult males with an associated reduction in AAA (Elton et al, 1959) and carbonyl lipids, which appear related to the production of cortical hormone (Alpert, 1950). The pattern of these responses is interesting - the weight gains are typical but in this species they reach a maximum within 3 hours rather than the expected 38-40 hours as shown in the rat; the AAA level is reduced and then returns to normal, as in the rat, but then decreases again rather than exceeding the normal level as would be expected.

ACTH has also been shown to increase the secretory rate of the gland so the general functional pathways appear normal within this species although their thresholds and specific patterning of responses is different.

ii) FORMALIN:

This substance is often used by injection as a stressor, and should cause the release of ACTH with associated adrenal changes. Alpert (1950) found the response in young adult males to be the same as with direct stimulation with ACTH.

iii) DESOXYCORTICOSTERONE ACETATE:

This drug is thought to have either a direct effect on the adrenal cortex or to inhibit ACTH secretion in the anterior pituitary. Isaacson (1949) describes this drug as having a progestational effect in the hamster. Alpert (1950) found that in all males injection resulted in a decreased adrenal weight (with a noticeable thinning of the zona glomerulosa), reduced body weight gain, changes in carbonyl lipids and AAA depletion (especially in older animals).

iv) DIETHYLSTILBESTROL:

This is a partial pituitary inhibitor with an effect on the gonadotrophic hormones, acting as a synthetic oestrogen. Injection resulted in reduced body weight gain, decreased adrenal weight with degenerative changes showing throughout the gland and atrophied testes. In immature males the AAA increased by 36% whilst in older animals the levels decreased by 10% (Alpert, 1950). Elton et al (1959), however, reported, no reaction in males but a rapid decrease in AAA in females. This effect was also investigated by Wexler (1951) who found the response to be marked in females, whilst only moderate in males with no indication of a sudden release in ACTH. The female gland also showed histological changes corresponding to the curve of AAA depletion and repletion whilst the male gland did not. Chronic treatment with this hormone results in renal tumours in all males and in some females which are known to be secondary to adrenal cortical stimulation and part of the GAS (due to the secretion of mineralcorticoids as well as 'stress' hormones).

v) EPINEPHRINE:

Deane and Lyman (1954) administered daily injections for 7 and 42 days in both males and females, and found no apparent body weight loss or change in adrenal size although after 42 days both male and female adrenals had increased slightly due to a widening of the cortex.

vi) HISTAMINE:

Holmes (1955a) found significant depletion of AAA within 1 hour of injection.

In general, then, the response to physiological stress in the form of drug injection in this species is somewhat atypical - compared with other common laboratory species (see Chapter IV). The males seem to respond less typically than the females, and this may have highlighted the problem due to the sole use of males by many experimenters. It is tempting to explain the results simply by referring to the sexual dimorphism in this species but the fact that the hamster is also a hibernator, a 'wild'-type and possesses the lipid-poor adrenal - all factors deemed to influence adrenal responsiveness by various workers - suggests a more unique physiology.

vii) GONADECTOMY:

As already mentioned gonadectomy affects the sexual dimorphism of this species - whether performed before or after puberty. The effects of this surgery are also important as they shed light on the intimate relationship between the gonads and adrenal function. This relationship appears particularly important in this species due to the overriding gonadal influence, particularly of progesterone, on the pituitary adrenal system - a finding common in hibernating animals.

In adult males, castration leads to a reduction in adrenal weight (Peczenik, 1942b; Keyes, 1949) which may be increased by administration of testosterone (Peczenik, 1944; Gaskin and Kitay, 1970) which increases the output of ACTH and hence glucocorticoid secretion (Gaskin and Kitay, 1971). In females the picture is not so clear although spaying is usually reported to increase adrenal weight (Peczenik,1942b) with no reversion of the effect of oestrogen administration (Peczenik, 1944) - the involvement of other physiological systems, such as a stress response, may be implicated. Prepubertal gonadectomy results in decreased adrenal weight in both sexes, and recovery also occurs to normal with testosterone treatment in males and oestradiol in females. Both the castrate and intact male adrenal weights are greater than the spayed or intact females (Gaskin and Kitay, 1970).

Castration also affects the metabolism of the adrenal gland - for example, both the resting and stress-invoked levels of plasma steroids are decreased; hepatic metabolism of cortisol is decreased;

the biological half-life of cortisol is increased; adrenal steroidogenesis (in vitro) and adrenal steroid secretion (in vivo) are decreased - all of which may be restored to normal levels by testosterone. There is little effect on any of these functions by ovariectomy in the female (Gaskin and Kitay, 1970). Wexler (1952) showed that the AAA depletion pattern also alters in gonadectomised animals - the male pattern closely following that of the female although at a lower level. Both males and females have about twice as much AAA as intact subjects.

viii) HIBERNATION:

Holmes (1955a) used AAA concentration as an index of adrenocortical activity as animals went through the pre-hibernatory period. The concentration of AAA increased rapidly to a maximum after 3 hours in the cold which was thought to reflect either decreased cortical activity or general metabolic activity, and that this concentration then decreased again so that after 48 hours the levels were normal. However, this response is in fact very similar to that shown by Alpert (1950) as the response to ACTH. Hibernation may therefore be triggered in this species by a stress response to cold (see below) under appropriate environmental circumstances. Preparation for hibernation is accompanied by decreased body weight and an inactive reproductive system, although no changes occur in the adrenal weight. (Hoffman, Hester and Towns, 1965). The typical increase in brown fat tissue of hibernators is shown.
During hibernation both AAA concentration and adrenal weight are equivalent to that of control animals, although female adrenal weight has been reported to decrease and become less variable (Deane and Lyman, 1954). Lyman and Leduc (1953) also found that carbohydrate metabolism was maintained by adrenal activity to near normal levels during hibernation. The levels of cortical steroid drop dramatically, as does body temperature and general metabolism (Deane and Lyman, 1954; Lyman, 1948) on entering hibernation.

On arousal, there is rapid synthesis of adrenal cortical steroids to a normal level within 6 hours. There is no storage of these materials in the adrenals (Deane and Lyman, 1954) but there is some storage of materials in the hypophysis. This suggests that synthesis is under pituitary influence (see Soumalainen, 1959 cited by Denyes and Horwood, 1960). The ability to hibernate is lost following adrenalectomy.

ix) COLD EXPOSURE:

In this species, which has the ability to hibernate, cold exposure does not appear to constitute sufficient stimulus for the pituitary to release adrenotropin nor thyrotropin, as no hypertrophy is observed in either the adrenal or thyroid glands (Deane and Lyman, 1954). It is only when the animal actually enters hibernation that metabolic changes occur, as mentioned above.

However, there is a good deal of conflicting evidence in this area which suggests that adrenal gland activity is dependent on a number of factors including the duration of the cold exposure, the actual temperature experienced and the nutritional state of the animal. In many respects the cold-stressed hamster is similar to one arousing from hibernation.

x) ADRENALECTOMY:

In both males and females this operation results in at least a 25% loss of body weight (Snyder and Wyman, 1951) although the females survive significantly longer than the males. Further evidence from older females, those in extended metestrus and those that had been ovariectomised in addition to the adrenalectomy has indicated that some ovarian secretion may, to a degree, protect the female from the effects of adrenal gland removal. This ovarian secretion is now known to be progesterone and its administration will maintain an adrenalectomised hamster. This is also true for the rat but the hamster is more responsive to progesterone treatment (Emery and Greco, 1940).

Overall, then, one can conclude that differences between species, ages and expression of sexual dimorphism is dependent on an hormonal balance, unique to each species, within the pituitary adrenal tissue axis that acts upon the tissue with varying sensitivity to hormonal stimulation.

Psychological Studies

For exactly the various reasons stated above hamsters have found more use in medical and physiological research than in psychological research despite recommendation by several workers (e.g. Pearl, 1963a). General measures have been made using the open-field and exploratory situations, in which significant species differences have been shown (Hughes, 1969), illustrating the different patterning of behaviour appropriate to a species. Typically in the open-field the golden hamster produces a relatively high score on day 1 with subsequent days given lower and similar scores due to decreased mobility with increasing familiarity (Gerritz, 1971), resulting in a J-shaped curve over a conventional 4-day open-field test. The reversal of the sexual dimorphism normally expected in laboratory animals is demonstrated behaviourally in the open-field with the female being more active and less fearful, as shown by lower emergence times, than the male - and this difference increases with age (Swanson, 1969; Scott, 1970). Defecation in the hamster, unlike the rat (where it is often used as an open-field measure in itself) is rare, as is grooming. The low level of defecation is unfortunate as the measure is more useful as an emotionality index than ambulation, which is mainly exploratory (see Broadhurst, 1957), although this later may be greatly influenced by the amount, and type, of handling the subject receives. The actual manner of locomotion could probably be incorporated into a reliable measure of emotionality by observing the amount of 'freezing' occurring, the ease with which the animal crosses the open-field and the closeness of the abdomen to the ground (this last indicator is subjectively convincing). The levels of activity are also affected by the time of day and physiological state of the animal.

Novelty has been shown to be reinforcing (see Sykes, 1962), as with other species, but deprivation of novelty does not cause any increase in incentive, (Schneider and Gross, 1965).

A number of comparative learning studies have been completed using both active (Pearl, 1963b; Babbini and Davis, 1967; Hussey, 1971) and passive (Walters and Abel, 1971) avoidance learning, and mazelearning (Bowland and Waters, 1955). The consensus of opinion appears to be that golden hamsters are inferior in their learning ability to the laboratory rat - however, several workers (Pearl, 1963a; Babbini and Davis, 1967; Walters and Abel, 1971) have stated that the species differences were due to interactions of species specific reactions and the particular behavioural task under study - rats are invariably the 'best' learners when compared with hamsters, mice, guinea pigs or gerbils and it must be remembered that these tests are invariably designed with, and for, rats. The hamster appears to have particular trouble in learning a one-way locomotor avoidance response with a visual CS rather than an auditory CS, compared with the rat (Babbini and Davis, 1967). This finding well illustrates the dependence on experimental procedures in cross-species studies as improved escape latencies demonstrated that there was no general learning deficit. This point is emphasised by the mazelearning studied by Bowland and Waters (1955) who found that, although the two species showed no significant differences on conventional measures of learning in this situation, incidental measures gave very different results showing that some responses are more apt in one species than another.

In a visual discrimination learning situation Sykes (1962) found that brightness discrimination occurs rapidly but that form discrimination learning was slow. Once achieved, however, transfer learning and generalisation to rotated figures, outlines and size alterations occurred though figure-ground reversal resulted in complete breakdown in discrimination. The results obtained, particularly with regard to outlines, are at variance with those known for rats but this was again attributed to methodology rather than different learning skills.

Early Experience in Hamsters

i) LITTER SIZE

This was one of the variables investigated by Scott (1970) using litters with 1 or 8 pups, the single litter pup was female and only females in the large litters were tested; they were also compared with litters sized 2 and 8, containing both males and females, which had been handled daily in the preweaning period. This handling was not carried out in the standard manner (see, e.g. Wells, 1975) due to high levels of cannibalism and, instead, involved handling the pups with small spoons. Open-field testing (3-day) was carried out when pups were aged 30-32 days.

Animals from small litters were significantly heavier (males more so than females, although this sex difference was not significant) whether they were handled or not. Pups from large litters were significantly more active in the open-field, although small litter pups were more active in the outer sections area on day 3. However, handling caused these differences to be lost. There were no significant differences between the groups regarding incidental behavioural measures in the open-field.

These results appear to support the hypothesis that the larger litters, obtaining more early stimulation, were more active and less emotional in the open-field (as shown by day 1 data - see Whimbey and Denenberg, 1967). However, to conform to the accepted response to extra stimulation in rats, this should have corresponded with better growth and faster development which was in fact shown by the small litters in this species. The interaction of a nutritional factor cannot be ignored as a possibility of interpretation - for example, the smaller pups in the large litters may have, in fact, been undernourished - a condition known to increase activity levels in the rat.

ii) ISOLATION/DEPRIVATION STUDIES

Although preweaning isolation is reported to have little effect (Scott, 1970) postweaning isolation causes, at least in the female, increased nervousness, excitability and reaction to novelty. This seems to be effected by interference in the development of processes which reduce inter-animal conflict and is supported by the numerous reports of increased aggression in isolated females (Wise, 1974; Brain, 1972).

However this increased aggression is not accompanied by any changes in either adrenocortical activity or gonadal function (Brain, 1971). In the male, too, there are reports of increased aggression and this is accompanied by increased gonadal function as found in the house mouse. Although androgen levels are known to affect the production of ACTH and hence glucocorticoid secretion (Gaskin and Kitay, 1971) no evidence of increased adrenocortical activity was reflected in the plasma cortisol levels although the isolated males had significantly heavier adrenals. This report contradicts earlier results suggesting that isolated animals may secrete up to twice as much cortisol as grouped animals (Hoffman et al, 1968). Variations may well be occurring in this data due to differences in housing conditions as Brain and Nowell (1970) have suggested that paired, rather than grouped, animals are in fact in a highly stressful situation due to the continual dominant/subordinate relationship.

The effect on social behaviours in adult male hamsters of isolation was shown to have no effect (Gerritz, 1971). The social behaviours in preweaning olfactorily-isolated hamsters is also unaffected, although the development of fighting behaviour is somewhat retarded (Dieterlen, 1959). These isolates also tend to mature more slowly physically than grouped animals.

iii) ENRICHED ENVIRONMENTS

No report could be found in the literature on the effects of a free enriched environment in the golden hamster, so a pilot study was carried out in this department and is reported in full in Chapter VI, Section I. One experiment, by Anton et al (1972), in which golden hamsters were given early experience in a visually enriched environment, showed that later form discrimination was improved, although manipulation of the shaped objects (in this case circles and triangles) during this time gave no additional gain in perceptual learning. Another experiment however, see Lawlor et al (1975), in which enrichment - in the form of novel objects being introduced to the home cage daily, days 14-27 - was used as one of the independent variables, seemed to counter this finding. The enrichment led to improved viability, a decreased emotionality as shown by the open-field, but an inability to even attain the standard level of correct responses in a simple discrimination task. The enrichment variable was also combined with handling in another experimental condition and this combination

"....can only be regarded as a biological disaster" due to the poor viability and weight gain. It seems, therefore, that whilst specific perception learning may occur in this species the overall improvement due to general enrichment, which appears related to the underlying effect on "emotionality" of the continuous free-environment, at least in the rat, does not occur.

There have been two studies, both socially orientated, on the effects of colony living in the golden hamster (Goldman and Swanson, 1975; Frey, 1966). Both reported difficulty in building up the colonies due to greatly disrupted maternal behaviour and litter care. Although marking occurred no territories were established and it was only if females managed to isolate themselves within the environment that pregnancies reached parturition. Aggression increased greatly in the males and both sexes, though especially pregnant females, showed escape behaviour. Goldman and Swanson also found that the density of the population was controlled to a large extent by a dominant pair in that other females had atrophied sexual organs.

It seems likely that these colony environments were too artificial when compared with the probable natural habitat - both with regard space and population density - and so produced aberrations in behaviour and reproductive physiology which are possibly stress-linked.

iv) HANDLING

The first report of the effects of handling on hamsters were from Yaron et al (1963) who used a postweaning gentling condition (in a calm quiet environment) compared with stressful forceps handling (in an aggressive noisy environment). He found that levels of aggression decreased and maternal care was much better in the case of the gentled animals indicating that, at least in the adult animal, the intensity of the stimulation is an important variable in the effect it produces. It has since been confirmed by several reports (Groen, pers. comm.) that handling an adult female results in a decrease in aggression, allowing pairs to be kept together, and a very rare neglect of young.

In an experiment on the effects of early administration (day 2) of gonadal hormones on open-field activity Swanson (1967) found the scores for ambulation in the open-field of the control group higher than in a previous experiment. This increase in activity occurred in both sexes and was attributed to the handling received, both at the time of hormonal-placebo injection and during the following weeks (twice weekly) for weighing. There was also a significant interaction between sex and handling. The emergence times did not give any significant differences although they decreased in the handled female and increased slightly in the handled male. These results were confirmed (Swanson, 1969) when handling animals at one week, together with weekly weighings, also produced higher ambulation than controls when tested at 100 days.

Scott (1970), who handled daily from days 3-30, reported no elevated body weights as have been shown in many rodent experiments nor any increased activity due to lowered emotionality. (The applicability of relating activity in a test situation to emotionality in the golden hamster is assumed although there is no direct evidence - see Sodetz, Matalka and Bunnell, 1967). Unusually the activity scores in both sexes increased over days of testing (males showing a more extreme gradient than females) - it must be remembered, however, that these animals were tested whilst still immature (days 30-32) immediately posthandling.

A further experiment by Lawlor, Wells and Weinberg (1975) in which the animals were handled daily days 0-21 gave very deleterious results. The handled animals had impaired viability, poor physique and body weight gain with slightly increased ambulation in the open-field and poor learning ability compared with the control groups. They concluded that the handling procedure in this species was physiologically damaging, possibly due to the early maturation of the stress response in these animals.

The general picture of early experience in the hamster is not then very clear, with the animal responding to the various treatments but not always in the manner expected. The rearing condition of this animal has also been shown to affect normal maintenance behaviours such as hoarding (Bevan and Grodsky, 1958), dietary preferences and general behavioural repertoire (Hoffman <u>et al</u>, 1968) and Riess (1954) respectively.

It therefore seemed that as this species did not necessarily respond in the same manner as the rat, although being sensitive to manipulation, it was a useful subject for comparative study.

The apparent contradiction of the above researchers' results into effects of handling in the hamster are considered here in order to formulate some hypothesis for investigation in this research. An obvious difference between the experimental conditions of Lawlor et al (1975) with those of Swanson (1969) and Scott (1970) is that the former workers initiated handling continually from day 1, Swanson handled irregularly and Scott did not handle until day 3. This latter is explained as an attempt to minimize cannibalism on the part of the mothers but is rather a reflection of poor experimental technique. Prenatal stimulation in the form of increased illumination levels during gestation, is, together with handling of the mother, normally thought to increase emotionality (Morton, 1968) although it has been shown to result in a decrease whilst auditory stimulation of females led to increased emotionality in the offspring as expected in rats (Jolley and Dreesman, 1973). This finding of prenatal stimulation effects (see Morton, 1968 for a general discussion) may have some bearing on the differences found between species in studies on early experience due to a relation between onset of stimulation and the level of development of the adrenal system or hypothalamus at that time; these organs generally being attributed with vital roles in the production of the effects of infantile stimulation. In some respects one may be validated when attempting to delineate equivalent periods of development in ignoring birth and treating embryological and neonatal development as a continuum.

As already mentioned, in the hamster there is real evidence that the organism is born in a less mature state than the rat due to its extremely short gestation period. Several workers have demonstrated variation in development, as compared with other laboratory rodents, of both behaviour and physiology which they attribute to this fact (see Buchanan and Hill, 1949; Hissa and Lagerspetz, 1964; Smalley and Smalley, 1967; Richards, 1966a; Okon, 1971; and Daly, 1976). It is therefore suggested that the contradictory results obtained from handling hamsters may be explained - by early handling occurring during a period of development similar to that of a prenatal rat and later handling occurring during a period of development closer to that of a postnatal rat. This makes a rough approximation to the effects obtained by those workers who have handled hamsters - although the possibility that the variation in result is simply due to strain differences or, especially in the case of Swanson (1969), the actual and overall parameters of the experimental technique, cannot be ignored.

Whilst studying the literature, several pointers seemed to indicate that there was indeed a difference in the state of the newborn hamster when compared with an older neonatal animal or with a newborn rat. In a study on the postnatal maturation of the hypothalamus in the hamster, Auer (1951) consistently found that in the first 3-5 days post-partum, cell multiplication was still active with specific structuring occurring only towards the end of this period. In the rat this occurs predominantly prenatally, particularly cell multiplication (Palkovits and Mitro, 1968). The fact that the hamster is still experiencing cell multiplication postnatally, whilst the rat is largely differentiated, makes this a particularly vulnerable period of development in which other factors may be effective (Dobbing and Smart, 1974).

Himwich (1973) has used brain weights to equate the maturation of the rat days 0-26.5 postnatal with days 3.3-17.4 postnatal in the golden hamster.

Records of the electrocorticogram (ECoG) in the developing hamster (Callison, Himwich and Turner; 1973) do not show sustained cortical activity until the fifth postnatal day. Anatomically, the newborn cortex is very immature in appearance with no clearly defined morphological components except the densely packed neurons. During the first 5 days postpartum gradual lamination of the cortical layers occurs. These findings confirm those of Shimada and Langman (1970), who described the primitive appearance of the hamster cerebral cortex on the first postnatal day, noted that cell migration was still proceeding and differentiation was not yet complete - but that by the fifth postnatal day the 6 cortical layers were relatively distinct, neuroblast migration had ceased, and cell differentiation was proceeding rapidly.

ECoG recordings have also been obtained for rats and mice showing that sustained cortical activity is first apparent in these two species at 5-6 days (equivalent to 5 days in the hamster) and becomes adult in type at 13-15 days in the hamster, 16-17 days in the mouse (Kobayashi et al, 1963) and at 21 days in the rat (Deza and Eidelberg, 1967). The hamster, then, is not unique in having discontinuous cortical activity immediately postnatally although as it matures more rapidly experimental manipulation may well produce differential effects (see King and Eleftheriou, 1959).

There is also evidence to suggest that the adrenal cortex in the newborn rat, whilst responding to stressors (Denenberg et al, 1967), is less responsive postnatally than prenatally (Josimovich et al, 1954) than that of the newborn hamster (Hillman and Seliger, 1975) - yet another factor that may influence the response to experimental manipulation; and an important step in the suggested physiological mediation for handling effects.

This thesis therefore attempts to elucidate the findings of handling effects in the hamster and to test the hypothesis that very early handling in this species produces deleterious effects due to some interruption or disruption in hypothalamic maturation. The critical period for the handling to be effective in this respect was determined, from the literature, to be days 0-4 in the neonatal organism. It is necessary to propose some physiological rationale to support theories of critical periods, as arguments against such theories, particularly in handling experiments, include the frequent lack of evidence in observable detail to delineate such a period. There are in fact many physiological changes with behaviourable consequences during development, as described by Scott (1958) for the dog, that are related to maturational levels. Bearing in mind what has already been stated above for prenatal stimulation, an example of a point in maturation before which a stimulus will elicit one response whilst the same stimulus later results in a different response is given by Feigley (1974). He found that administration of scopolamine disrupted aversive learning in postweaning rats (aged 20-28 days) whilst having no effect in immature rats (aged 16 days). This result was considered consistent with the hypothesis that a cholinergic inhibitory system which mediates passive avoidance develops in the rat 16-20 days postnatally.

Such systems are obviously implicated in the handling phenomenon and the final outcome must result on the maturational level of the organism involved.

IV. COMPARATIVE SURVEY

IV. COMPARATIVE SURVEY

This section is concerned with the hamster in relation to other species, mainly prodents, commonly used in the laboratory, as it seems - apart from the differences in social behaviours and lifestyle - that there is a common assumption that this species is basically similar to the rat in its responses. Bearing in mind the known differences already mentioned it is hardly likely that they would be. I have therefore surveyed certain areas - basically those of development and physiology, in addition to early experiences, in which these species may differ. The survey of these two fields is not exhaustive, but outlines the main points pertaining to the present study.

Development

The basic point to be made in this context is that, due to their extremely short gestation period, the golden hamster is less mature at birth than the rat and also develops much faster (Buchanan and Hill, 1949). The gestation periods and developmental data for the rat are listed below (Tables 5,6,7,8 and 9), and the difference must be borne in mind whilst making comparisons between the species and in the design of experiments which attempt to compare them. It is possible from studying development data to equate lengths of time in the development of one species with that of another, as Waterman (1948) and Himwich (1973) have done for certain measures (see Appendix B for details of equivalent age periods) on a wider spectrum of species.

The development of brain systems is well-documented (see Timiras, 1972; Auer, 1951; Altman, Das and Anderson, 1968; Caley and Maxwell, 1968; Eayrs and Goodhead, 1959) and shows that the hamster has a longer postnatal differentiation period than the rate and, at least in the early postnatal stages, there is a large discrepancy in the amount of proliferation that has occurred within the cerebral cortex. This is demonstrated by the much longer time span required for myelination within the hypothalamus of the hamster to occur (Hissa and Lagerspetz, 1964), (the lab mouse is more similar to the hamster in this respect). However, the development of the caudal-rostrol sequence in the brain is similar in the rat and hamster as demonstrated by preweaning activity and arousal states (Campbell and Mabry, 1972; Bronstein, Neiman, Wolkoff and Levine, 1974) so a rigid comparable time sequence is not possible.

TABLE 5: Comparative developmental data
(Spector, 1956; Denenberg, 1972; Farris, 1950)

Species	Gestation Time	Weaning age	Onset of female puberty
Golden hamster	16 days	21-30 days	38-50 days
Rat	21-23 days	21-30 days	50-60 days
(Mouse	19-20 days	21-30 days	37-54 days)

TABLE 6: Comparative behavioural development

Age	Species		Source
Day 1	Rat	Self-righting	Altman & Sudarshan, (1975)
2.5	Rat	Startle reflex	Altman & Sudarshan, (1975)
7	Rat	Swift cliff avoidance (growth of vibrissae)	Altman & Sudarshan, (1975)
9	Rat	Self-licking	
9.5	Rat	Righting reflex	Sykes & Cheyne, (1976)
13	Rat	Vertical activity	Sykes & Cheyne, (1976)
14-15	Rat	Normal walking (on rough surfaces)	Altman & Sudarshan, (1975)
15	Rat	Horizontal activity	Sykes & Cheyne, (1976)
16	Rat	Running	Altman & Sudarshan, (1975)
18	Rat	Rearing responses (hindlimbs functionally mature)	Altman & Sudarshan, (1975)
19	Rat	Rearing	Sykes & Cheyne, (1976)
21	Rat	Many locomotor skills shown, though more complex skills still maturing.	Altman & Sudarshan, (1975)

TABLE 7. Comparative physical development

Age	Species		Source
Day			
5	Rat	Geotactic response established	Altman & Sudarshan (1975)
7-8	Rat	Forelimb digits separated	Altman & Sudarshan (1975)
7-14	Rat	Crawling	Altman & Sudarshan (1975)
9.5	Rat	Teeth appear	Sykes & Cheyne (1976)
10-11	Rat	Hind limb digits appear	Altman & Sudarshan (1975)
14	Rat	Hair growth complete	Sykes & Cheyne (1976)
14-15	Rat	Eyes open Walking developed	Altman & Sudarshan (1975)
17	Rat	Ears open	Spector (1956)
17.5	Rat	Eyes open	Sykes & Cheyne (1976)
37-67	Rat	Vaginal opening	Spector (1956)
50-60	Rat	Sexual maturity	Farris (1950)

TABLE 8: Comparative physiological development (embryological)

Age	Species		Source
Day			
6-8	Mouse	Primitive streak	Waterman (1948)
			Waterman (1948)
8-9	G. Hamster	Primitive streak	
8-9½	Rat	Primitive streak	Waterman (1948)
10	Mouse	Anterior limb buds appear	Waterman (1948)
12	Rat	Anterior limb buds appear	Waterman (1948)
13	Rat	Neural tube closed, formation of CNS begins	Tilney (1933)
	Rat	General cortical differentiation appears	Tilney (1933)
15-16	Rat	Testes appear, sexually differentiated	Willier (1924)
17-19	Rat	Anterior pituitary developed ACTH active	Willier (1924)
18-19	Rat	Thyroid developing	Willier (1924)
17	Rat	1^{o} migratory lamination ends	Tilney (1933)
19	Rat	2^{o} migratory lamination ends	Tilney (1933)
21	Rat)) Mouse)	Birth	

TABLE 9: Comparative physiological development (postnatal)

Age	Species		Source
Day 0	Rat	Cortex undifferentiated, tightly packed cells in columns. Deeper in cortex-neuroblasts well differentiated, growth of cell processes.	Caley & Maxwell (1968)
		Cortex layered from 2^{o} migratory lamination, not very well differentiated.	Tilney (1933)
		Thalamic nuclei defined. 3^{o} migratory lamination begins - divisional cortical differentiation. Cortex largely undifferentiated cells.	Beckoff & Fox (1972)
		Elementary cortical differentiation, adult liminar arrangement not seen. Neurones very closely packed throughout cortex, few axons present.	Eayrs and Goodhead (1959)
0-7	Rat	Electric activity cortex irregular, intermittent, low amp, "silent" periods common.	Crain (1952)
0-6	Rat	Cortical layers 3 & 4 seen (due to increased cell size & spacing) rapid decrease cell/grey coefficient	Eayrs & Goodhead (1959)
5	Rat	Local cortical differentiation begins → marked development in second week.	Tilney (1933)
5-6	Rat Mouse	Sustained cortical activity	Callison et al (1973)
7-10	Rat	Trend towards regularity, rhythmicity and continuity in electrical activity cortex, no silent periods	Crain, (1952)
5-10	Rat	Sharp increase in volume and thickness of cortex.	Sugita (1918)
6-12	Rat	Cortical layer 5a seen, dendrites appearing.	Eayrs & Goodhead (1959)
9-23	Rat	Critical period of biochemical development in brain.	
10	Rat	Intracortical myelinisation begins	Jacobson (1963)

Age Day	Species		Source
10	Rat	Many mature synapses in cortex, break between immaturity & adulthood.	Caley & Maxwell (1968)
10	Rat	N^{o} cortical neurones/unit vol. ÷ adult. Nuclei of cortical neurons maximum size. Nissl bodies rapidly becoming abundant.	Sugita (1918)
12	Rat	N^{o} dendrites ÷ adult	
12-18	Rat	Rapid multiplication and growth dendrite branches, maximum increase in axon density.	Eayrs & Goodhead (1959)
14→	Rat	Blood vessels invade cortex, loss of spaces.	Caley & Maxwell (1968)
14	Rat	Amps larger in ECG Patterns basically similar to adult. Cortical cells differentiated Thalmocortical fibres begin myelinating.	Crain (1952) Beckoff & Fox (1972) Jacobson (1963)
16-17	Mouse	Adult ECG developed in cortex.	Callison *et al.* (1973)
17-23	Rat	Develops forebrain cholinergic mechanisms	Bronstein *et al.* (1974)
18-30	Rat	Maximum myelination hypothalamus - maintain homeothermy.	Hissa & Lagerspetz (1964)
18	Rat	Cortical structure ÷ adult qualitatively.	Eayrs & Goodhead (1959)
18-24	Rat	Maximum increased dendrite density	Eayrs & Goodhead (1959)
21	Rat	Adult ECG developed in cortex Vascular pattern, minimum extra-cellular spaces ÷ adult structure.	Callison *et al.* (1973) Caley & Maxwell (1968)

Age	Species		Source
Day			
44	Rat	Myelin formation on bars axon complete	Jacobson, 1963
		Myelin formation on thalamus complete	
60	Rat	Adult stage myelinisation reached.	Jacobson, 1963

Similarly, the development of locomotor and behavioural action patterns shows variation in emphasis both between species and between strains (see Daly, 1976 for the hamster; Altman and Sudarshan, 1975 for the rat; and Elwood, 1975 for the gerbil); and these may generally be surmised to have adaptive significance. For example, the Djungarian hamster develops grooming rapidly postnatally and shows self-covering - which may reflect its extreme natural climate as compared with the golden hamster. Explanations are not always immediately apparent - the rat neonate grooms and self-rights much earlier whilst rearing and eating later than the golden hamster - but are usually dependent on factors relating to parental care and environment. Simple relations with maturation or age from conception are not apparent.

Physiology

As already mentioned in the section dealing with the golden hamster, the hamster is similar to other laboratory rodents in general, although many of its organs have been adapted for desert living - possibly making comparisons with the gerbil more obviously appropriate than with the rat. A unique difference does exist between the hamster and other well studied rodents with regard to the immunological tolerance of the hamster and also with respect to its greater sensitivity to various natural hormones coupled with greater tolerance to lethal doses of several drugs. One poisonous drug to which the hamster is very resistant, about 100X more than man, is colchicine (Billingham and Silvers, 1963), and this is thought to be an adaptation to its native Syrian desert where it probably fed on the autumn crocus (colchicum). Such an adaptation is typical amongst desert rodents in order to feed from plants available, even where those plants have evolved their own protective mechanisms (Hanney, 1975). No such mechanism has been found in the grey Norway rat whose natural habitat is much more temporate and humid.

Sexually the hamster differs from the laboratory rat in its very early puberty and seasonal variation in fertility. The male golden hamster also shows less rigid sexual differentiation which is thought to lead to the reversed dimorphism in this species. Sexual dimorphism is apparent in any species where the male and female organisms are distinct - typically, with with to both their physical and behavioural attributes.

In the laboratory rodents the usual sexual dimorphism is reflected in the males larger size, greater activity and increased aggression. In the hamster these are characteristics of the female. In both the male rat and mouse neural differentiation occurs within the first few days of life to determine masculinity.

No such differentiation occurs in the golden hamster and if the male is castrated it will show female sexual behaviour (Payne and Swanson, 1973). This results in both behavioural and physiological reactions to stimuli being reversed in the golden hamster compared with the rat (see, for example, Swanson, 1966).

Differences also exist within the endocrinological system - though whether these are due to the environmental influences on the hamster causing annual rhythms or to the reversed sexual dimorphism is unclear. For example, in darkness the thyroid of the hamster shows increased activity whilst that of the rat(1) does not. Also this activity change is not reflected in morphology as it is in other species.

The adrenal cortex differs histochemically and structurally between the hamster and the rat. In the golden hamster sex differences occur in the reticularis with the male having larger cells resulting in a broader, heavier cortex associated with higher steroid secretion and faster metabolism (Zieger, Lux and Kubatsch, 1974); whilst in the rat the sex difference appears in the outer fasciculata and it is the female that has the heavier gland and faster metabolism (Parkes, 1945).

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(1) When rats (and mice) are referred to they are always laboratory animals, unless specified otherwise. This is an important point to remember as physiology and behaviour of wild animals seems very different from that of laboratory animals of the same species - see, for example, Woods, 1957. In many respects the laboratory rat and mouse are more like each other than either is like its 'wild' conspecifics. What little evidence there is (Murphy, 1971) suggests that such an intraspecific difference is not present in the golden hamster (see also Appendix G).

Adrenal Physiology

Looking at this area of physiology in more detail it is apparent that the golden hamster is very different from other commonly used rodents - and this has particular relevance due to the involvement of the pituitary-adrenal axis in the field of early experience. The adrenal cortex of the rat (together with man, guinea pig, dog and rabbit) is lipid-rich whilst that of the hamster (together with most hibernators, most ruminants and many 'wild' animals) is lipid poor, as stated above.

This distinction in adrenal type therefore does not follow the lines of taxonomic classification within the mammalian order, or even beyond it; physiological processes often fail to follow taxonomy and thus makes any simple assumption of 'likeness' based upon it untenable. Since the rat and the hamster differ so markedly in adrenal function, it has been necessary in this section to draw attention to those species which have been classified <u>either</u> with the rat <u>or</u> the hamster with respect to adrenal physiology.

Lipid-rich adrenals accumulate large amounts of cholesterol (the main steroid precursor) and other lipids - up to 12% wet weight in the rat adrenal; are slower at synthesising and faster at secreting steroids; and there is a close correlation between lipid and ascorbic acid content and functional activity (Schindler and Knigge, 1959; Lloyd, 1972). It is important to remember that the actual responses seen to stressors, using such measures, in a particular species is dependent on the relative rates of repletion and depletion of adrenal metabolites.

Lipid-poor adrenals, however, have small or negligible amounts of cholesterol - 5% wet weight of hamster adrenal is lipid and this has been shown to be mainly structural lipid - showing non-storage of cholesterol as a steroid precursor. The blood flow through the adrenals is similar in all species but the plasma steroid concentration in the hamster is 4-10X less than in other species. The rate of secretion in the hamster is 3-10X less than that in the monkey, dog, cat, ox, ferret and rabbit and 16-48X less than that of the laboratory rat (Schindler and Knigge, 1959). The fact that amphenone-B produces increases in corticoid production and accumulation in the rat, dog, calf and man but not in the hamster demonstrates the difference in adrenal metabolism of these species (Marks, Alpert and Kruger, 1958).

Snyder and Wyman (1951) propose that differences in adrenal morphology and physiology shown by sex, age and species are dependent on differences in the homonal balance within the pituitary-adrenal-ovarian-tissue cell axis acting on tissues to vary the sensitivity to hormonal stimulation.
Typically, domestic animals show lower adrenal weights and lower plasma corticosterone levels than their feral counterparts and this has continually been demonstrated in the rat (Benedict and Petrik, 1930; Woods, 1957). The wild rat has an adrenal weight 2-3X that of an albino laboratory rat but this difference decreases in captivity (Watson, 1910 in Benedict and Petrik,1930). Further, the exposure of a feral species to stress (such as prolonged cold exposure) or ACTH does not result in a metabolic depletion of the adrenal cortex nor in eventual adrenal hypertrophy. Indeed, in several cases (of which the golden hamster is one) it has been shown that the alarm reaction to stress does not include an initial phase of adrenal cortical metabolite depletion. This, together with the lack of response to ACTH injection, implies variation in metabolism and differences in threshold to response. An example of the apparent resistance to stress in wild rats was demonstrated by Weinstein and Driscoll (1972) who used the standard practice of immobilisation with food deprivation in an attempt to produce gastric pathology in wild rats. Only after long food deprivation and 24 hours immobilisation was there any increase in the spontaneous rate of gastric ulcer formation, with again no change in the adrenals.

STRESS REACTIONS

In an effort to demonstrate what the sexual dimorphism of the golden hamster and its classification with 'wild' species* means in the context of its reaction to stressors, those stress reactions described in the previous chapter are considered here for compariso

i) ACTH

The administration of this hormone gives a very different pattern of AAA depletion and adrenal weight gain in the male rat or guinea pig from that shown in the male hamster (Alpert, 1950). In the rat and guinea pig one gets an initial fall in AAA followed by a great increase and a maximum adrenal weight gain in 38 hours compared with the hamster which shows the initial drop followed by a second drop and a maximum adrenal weight gain in 3 hours. This is thought to be a reflection of the different metabolic pathways in these species.

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*The gh may be considered a 'wild-type' animal from the available genetic, physiological and behavioural evidence - see Murphy (1971) and Lawlor (pers. comm. Appendix G).

In a large survey Elton, Zarrow and Zarrow (1959) showed that ACTH led to a decrease in AAA in the rat, guinea pig, opossum, female mouse and the male golden hamster whilst having no effect in ducks, quails, frogs, toads, cats, female rabbits and male chicks. These findings relating to AAA were in conjunction with findings relating to cholesterol levels - these were shown to increase in the frog but to show no alteration in toads, chickens, opossums, rabbits, cats, dogs or mice. It was suggested by these workers that comparison with findings from other stressors would be useful in demonstrating both the effectiveness of stressors and the pathways by which they are effective.

It is unfortunate that neither of these workers observed the effects in both sexes of the species studies.

ii) Formalin

No data was found for the effect of this substance as a stressor in other species than the hamster.

iii) Desoxycorticosterone

The response reported by Alpert (1950) to this hormone in male golden hamsters is the exact opposite of what had been reported for rats (Sarason, 1943; Greep and Deane, 1949) with regard to lipid distribution - i.e., in the hamster the inner fasciculata and reticularis are depleted of their Schiff-stainable material whilst in the rat the hormone depletes the glomerulosa. Another variation in the hamster is a decrease in the rate of body growth rather than the increase over the normal that has been reported in other species. Despite these differences the overall finding of a slight decrease in adrenal weight appears common to most species.

iv) Diethylstilbestrol

The AAA concentration in response to a single injection of diethylstilbestrol is similar in female golden hamsters and rats in that there is an initial decrease followed by a compensatory increase (i.e. as with ACTH) whilst male or gonadectomised hamsters show no such compensation (Wexler, 1951; Sayers and Sayers, 1948). Alpert (1950) showed male golden hamsters reflect their response in a loss in adrenal weight whereas one would expect an increase in adrenal weight in lipid-rich animals. These changes seem mainly due to alteration in lipid content, as above.

v) Epinephrine

A decrease in AAA occurs in response to epinephrine in rats (Elton, Zarrow and Zarrow, 1959), but not in the hamster. Therefore these findings are in accord with what has already been stated concerning the adrenals of these species.

vi) Histamine

There is a significant depletion in AAA within 1 hour of injection in both rats and golden hamsters (Homes, 1955a). This is therefore a dissimilar reaction from that given to other stressors, such as above, indicating that there must indeed be different effective pathways for individual stressors.

vii) Gonadectomy and the effects of gonadal hormones

Comparison of the golden hamster and the rat in this regard shows the very different hormonal organisation operating in these two species. Keyes (1949) reports that gonadectomy in the hamster results in an increase in the size of the zona glomerulosa in the adrenal cortex whilst the same operation in the rat results in a decrease in size of the zona glomerulosa. If gondadectomy is performed prepubertally opposite reactions are then obtained in these two species in response to gonadal hormones - for example, weight loss may be recovered in the gonadectomised animals by treating the rat with oestradiol and the hamster with testosterone.

These types of findings have been replicated often and show that in the rat testosterone leads to decreased adrenal activity, reflected in the small adrenal of the male (Parkes, 1945) whilst oestradiol is very effective in promoting activity. The female rat adrenal will also decrease with androgen administration (Hall, 1940). In the golden hamster, however, testosterone increases activity whilst oestradiol has little response. The gh. responsiveness and larger adrenals (i.e. enhanced pituitary-adrenal function) in the male golden hamster are therefore explained by stimulative effects of testosterone in this species, whilst in the rat the female has the more vigorous pituitary-adrenal function due to the stimulative effects of oestradiol. This may be demonstrated in an adrenalectomised and oopherectomised rat preparation (Kitay, Coyne, Newsom and Nelson, 1965) - the administration of oestradiol leads to increased adrenal corticosterone production, increased ACTH secretion and increased hepatic metabolism of corticosterone; that is, a direct stimulation of adrenal function.

This does not, however, clarify the reasons for the different general pattern of response to stressors that occurs in the hamster as any direct relationship with the above would also presumably have to apply equally to other species - and this does not appear to be the case.

viii) Hibernation

As this is not seen in the rat, there is no basis for comparison with the golden hamster.

ix) Cold Exposure

Findings in this area include fluctuations in adrenal cholesterol levels in the rat but not in the hamster; some indications of decreased plasma cortisol in male golden hamsters, although no changes are apparent in the histochemistry of the adrenal; and an increase in plasma corticosterone in the rat - together with adrenal atrophy due to increased size of the zona glomerulosa, where most steroid production is thought to occur. The response of the rat, which is in accord with the GAS, is not shown by the golden hamster, and this difference is thought due to basic species specific differences in enzymatic action (Denyes and Horwood, 1960) under various conditions. Although certain physiological responses may differ changes in behaviour, such as increased nest building, occur in rodents, such as golden hamsters, rats and mice, and are controlled by thermoregulatory needs.

Woods (1957) showed that although laboratory rats responded to cold exposure with an increase in adrenal weight and increased absolute, although not relative, amounts of AAA in both males and females no effects on either the adrenal weight nor the AAA were shown in wild rats. This lack of adrenal response in wild rats was attributed to either a decreased sensitivity or an increased pituitary threshold to stressors. Other findings, such as those of Weinstein and Driscoll (1972), illustrate that this is a general finding in the wild species and not simply attributable to environmental stressors that the animal might naturally encounter.

The fact that hamsters typically show no adrenal response to cold exposure may be attributed to their hibernatory ability - most hibernators having the same type of adrenal physiology as the hamster, that is, the male adrenal is typically larger than the female and androgens induce adrenal enlargement.

x) Adrenalectomy

The effect of adrenalectomy is dependent on the state of the organism as periods of dormancy and low metabolism demonstrate (see Britton, 1930). This was also shown by Verne and Herbert (1951) in the increased survival rate of hibernators when cold-stressed following adrenalectomy. Both rat and golden hamster females survive longer following adrenalectomy than males due to the effect of progesterone. Golden hamsters are also more sensitive to progesterone than rats which may explain their improved survival, or add to the effect of being an hibernator.

Hypophysectomy, that is the removal of the pituitary, leads to atrophy of the inner zones of the adrenal cortex in both the rat and the golden hamster.

In conclusion to this section it may be stated that in the golden hamster, and particularly in the male, the adrenal is less easily stimulated by ACTH, and other stressors, than the adrenals of other commonly encountered species; and that under the influence of the hormone the hamster adrenal responds in a different manner to that of these other species.

This finding is common among 'wild' animals, hibernators and some avian species and emphasises the need to study a representative of these groups in the field of early experience - particularly when that species (i.e. the golden hamster) is in use as a laboratory rodent and fairly general statements are made within the field of early experience relating to the role of the adrenal system. It is thought that this lack of adrenal responsiveness is due to a lower sensitivity to stress and/or ACTH together with an increased responsivity to gonadal and seasonal influences (see Deane and Lyman, 1954). However, this does not appear to cause these animals to be more sensitive to environmental stimuli, rather than experimental manipulation, as demonstrated by the reaction of wild rats to cold exposure described above.

It is interesting that the golden hamster does not manifest any sign of domestication despite its long history of captivity (Murphy, 1971) although it has been argued that the high rate of spontaneous tumour formation (Fortner, 1958) and the disease known as wet-tail may be manifestations of the stress of captivity.

Psychological Studies

Basic behavioural differences in test situations have been shown between the golden hamster and other rodent species, which may probably be related to variations in basic activity cycles, for example, Aschoff and Meyer-Lohmann (1954) demonstrated the golden hamster to have an activity peak at the beginning of darkness, the rat showed two activity peaks in the darkness, whilst the mouse showed one activity peak at the beginning of darkness and one at the beginning of light. This was true whether using natural or artificial light, although there is evidence that different species are differentially affected by the different wavelengths (see Wurtman and Weiser, 1969). There is therefore a different basic structuring to each species behaviour and, probably, underlying physiology. Similarly, it has been commented on that there is no eliminative response in the golden hamster to the open-field as shown with rats and mice (Tobach and Gold, 1962) - a response considered a useful measure by many psychologists. When one realises that the golden hamster is a desert dwelling animal in the wild and an active hoarder this does not appear so improbable, (see also p.366).

Comparative psychological studies have been mainly concerned with social behaviours and learning. The social postures used by the common laboratory rodents (i.e. rats, mice, guinea pigs and golden hamsters) are basically similar (Grant and Mackintosh, 1963), and there is no direct evidence that the golden hamster deliberately seeks to avoid its conspecifics as may be implied by the proposed natural environment. Gerritz (1971) used pairs of male albino rats, guinea pigs, golden hamsters, gerbils and mice to demonstrate social responsiveness in the open-field and found golden hamsters to seek mutual contact as much as gerbils, twice as much as mice but only half as much as rats and guinea pigs. The golden hamster did, however, appear the least affected by changes in the experimental situation. The finding that the golden hamsters were more gregarious than the mice although less so than the rats appears contrary to the view that their behaviour, as a solitary animal, is different from that of a cosmopolitan, social dwelling animal such as a mouse or rat. It may well be that the use of males and the use of the animals in pairs in this experimental design leads to false impressions. Also, it is now apparent that the social organisation of social rodents is not so loose and large as had been thought - rather that within a given community there is an aggregation of smaller, separate social units, using single burrows and not an interconnected burrow system (Lore and Flannelly, 1977). Obviously, the combination of thoughtful experimental design with fuller understanding of natural conditions is essential in interpreting behaviours correctly. It must also be remembered that the behaviour of the wild animal may be very different from that of a laboratory specimen of the same species. Little evidence is available for the golden hamster except a finding by Murphy (1971) of no differences between the wild and lab-reared animals, although there is considerable evidence for behavioural and physiological differences between wild and laboratory rats and mice (Boice, 1973; Richter, 1959; Zerbolio, 1974). These include differences in activity, emotionality, response to novelty and in learning ability.

All common rodents typically show stable rank orders when caged in groups and these are generally simple arrangements based on aggression (Boice, Hughes and Cobb, 1969) but the manner in which this is attained and the underlying hormonal influences are very different. For example, aggression is typically controlled in many species by gonadal hormones with a simple rule being that androgens increase and oestrogens decrease the amount of aggression displayed (Johnson, Goy & Michels, 1962). This is true in the rat, but not in the golden hamster, where it is the female that fights more than the male due to the facilitating effect of female hormones upon aggression in this species (Payne and Swanson, 1973). Similarly, the expression of aggression may vary - in golden hamsters there is overt aggression and rank order is positively correlated with body weight whilst in, for example, gerbils, there is no overt aggression and no correlation of rank with body weight.

In exploratory and learning situations the common laboratory rodents show significant species differences due to basic differences in the patterning of their behaviour (Hughes, 1969; Bowland and Waters, 1955). Many specific learning tasks have been studied with the aim of determining which species is cognitively 'best' - and the results are almost exclusively explained by the interspecies variation in behaviour and response patterns rather than demonstrable learning deficits in any one or more species (Pearl, 1963a; Babbini and Davis, 1967; Walters and Abel, 1971). Species differences also occur in the ontogeny of memory processes associated with variation in maturity at birth (Campbell, Misanin, White and Lytle, 1974), and rates of subsequent development.

Evidence from the effects of lesions shows that species seem to differentially emphasise basically similar limbic functions. For example, in rats, terminations sites for limbic efferents are similar to those in other species but differ markedly in the number of fibres distributing to these sites. This may account for the lack of septal syndrome symptoms in those species which includes the cotton rat, when compared with those symptoms typically shown in the laboratory rat (Sodetz, Matalka and Bunnell, 1967). Similarly, although there are no differences in open-field behaviour in rats and hamsters with hippocampal lesions one gets opposite responses in these species under conditions of food deprivation (Jarrard and Bunnell, 1968).

In summary, this brief survey demonstrates the individuality of species both in simple maintenance behaviours and in complex cognitive and neurological responses. Such findings are important when attempting to define an overall general hypothesis for the effects of early experience, especially one with cross-species applicability - as a change in a specific behaviour of one species may not have the same meaning as a change of that some behaviour in a different, even closely-related, species. Certainly the laboratory rat and the laboratory hamster differ markedly in many underlying physiological processes and responses.

Early Experiences

This section only deals with those factors deemed relevant, and already detailed for the golden hamster (see previous chapter).

i) LITTER SIZE

Although this may seem to be a fairly straightforward variable; it may also involve undernutrition of the pups in large litters; and so be used by some experimenters to produce undernutrition (UN) effects. Experiments using variation in litter size have shown, in rats - an increase in hoarding and in emotionality in pups from large (12) litters, together with a decrease in maternal behaviour (Seitz, 1954); a decrease in plasma corticosterone levels and production of corticosterone in the adrenal together with an increased stress response in pups from small (4) litters compared with pups from litters containing 8 or 14 offspring (Macho et al, 1975); and changes in the development pattern of brain glycoproteins in pups from litters containing 3, 9 or 18 young (Cioffi, De Luca, Sadile and Di Benedetta, 1975). In mice, Castellano and Oliverio (1976) have shown larger litters (8 and 14 pups) to have delayed development of reflex activities and ECG, stunted brain growth and poor avoidance learning as compared with a control litter (4 pups). These effects differ in different strains as might have been anticipated with this species, possibly due to later development of brain functions.

These variations in postnatal nutrition and social environment therefore affect the animals' overall maturation resulting in changes in many of the indices typically associated with early handling. However, it is not the case that there is a simple relationship between level of stimulation (i.e. the larger the litter the greater the stimulation) and the affected dependent variable.

If we look at experiments involving the effect of undernutrition we find that it is typically produced by one of two methods - either undernutrition of the female which is thus passed on to the pups or by restricting the pups access to a lactating female. This latter type of experimental design often has a substitute female (non-lactating) for some period in the circadian cycle in an effort to prevent disruption of maternal - infant interactions (see Slob, Snow and deNatris-Mathot, 1973). In rats the results obtained have shown an increase in activity, especially in familiar, nonstressful situations (Smart, 1974; Raaijmakers and Sennef, 1975); lowered arousal threshold indicated by responses to shock and various learning situations - overall one may say there is an increased responsiveness to changes in the internal state with a corresponding decrease in the responsiveness to changes in the external environment; greatly reduced body weights and delay in growth, although this may improve gradually on an improved diet (Lynch, 1976; Howard, Olton and Johnson, 1976); a tendency for UN rats to be the active partners in social encounters when adult; some evidence for an increase in emotionality although this is not always the case (Levitsky and Barnes, 1970; Sykes and Cheyne, 1976; Raaijmakers and Sennef 1975); and changes in CNS development including retardation in acquisition of adult EEG, depression of postnatal cell acquisition and rate of DNA formation, reduction in both cerebral and cerebellar weights due to a permanent reduction in cell number (although brain weights are less impaired than body weights), and a decrease in cerebellar DNA (Gramsbergen, 1975; Balázs, Lewis and Patel, 1975; Howard et al, 1976). These effects show as learning deficits (Sykes and Cheyne, 1976) and in certain impaired motor functions (Lynch, Smart and Dobbing, 1975). The magnitude of these effects depends to a large extent on the degree and duration of the dietary restriction with the early weeks being critical.

Although Lynch (1976) shows that maternal care increases in rats with UN pups, Smart (1976) had previously shown that these females were in fact less efficient mothers. He found that these mothers had a very disturbed circadian rhythm of nest occupation and desertion, spending less time overall on the nest; the nest building itself was unaffected; they took much longer to retrieve their pups and did not lick them as much as control mothers; and they demonstrated a lot of other behaviours such as rearing which competed with the maternal behaviours.

ii) HANDLING

Denenberg, in Hafez (1962b), summarises the effects of this standard technique in the rat as follows: (i) improved avoidance learning; certain discrepancies which occurred in repeat experiments combining critical periods with handling indicated a relationship between the amount of stimulation and the learning performance although these have mainly been attributed to variations in the emotional response to the learning situation, and also an effect of strain difference due to the interaction between genotype and the infantile stimulation; (ii) a decrease in emotionality as shown in the open-field

which is reflected in the level of corticosterone in the blood (i.e. highest in the control group and lowest in the most handled group, Denenberg and Haltmeyer, 1967); (iii) increased exploratory behaviour and response to novelty, see also Wells (1975); (iv) increased weaning weights and adult body weights; (v) higher brain cholesterol levels; (vi) earlier maturation of the adrenal cortical response to stress as shown by AAA depletion; (vii) faster adrenal response to stress as shown by corticosterone levels in the plasma and (viii) smaller adrenals following stress.
An acceleration in development is often attributed to early experience - for example an acceleration of sexual maturation - but this also seems to depend on the intensity of stimulation as Mandl and Zuckerman (1952) found rough handling resulted in delayed vaginal opening, whilst Morton, Denenberg and Zarrow (1963), found gentle handling to advance the date of vaginal opening. The reduction in emotionality has also been reported in wild rats (Hughes, 1975) whose behaviour following handling was more like that of the domestic rat. Wachs (1974) has suggested that handling provides a 'buffering' effect allowing the animal to overcome fear in novel situations and so showing greater activity, increased exploration, etc.

Many workers in attempting to determine the behavioural mediator of the handling effect have studied aspects of mother/infant interaction and maternal behaviour. Bell, Nitschke, Bell and Zachman (1974) showed that handled pups produced higher rates and frequencies, together with longer duration, of vocalisations which resulted in higher rates of maternal retrieval and manipulation. Investigations along these lines have continued and show that not only are the females' maternal behaviours differentially affected by pup-produced stimuli - both auditory and olfactory - but also their adrenalcorticoid responsiveness, i.e. the behavioural studies now have physiological support (Smotherman, Wiener, Mendoza and Levine, 1977; see also Lee and Williams, 1974; Wright, Bell, Schreiber, Villescas and Conely, 1977; Villescas, Bell, Wright and Kufner, 1977).

This evidence has not prevented others from looking at the alternative hypotheses despite the difficulties involved in removing the influence of the mother. Williams, Bailey and Lee (1975) tackled the problem by handling the rat pups after early weaning at day 14 for eight days. They obtained long-term changes in both weight and behaviour normally associated with handling demonstrating that there is at least a component within the handling effect of a direct influence on the pups development. An argument against these findings is that Hofer (1975) has shown early weaning at two weeks to result in hyperactivity due to the loss of the female's regulating influence on the pups level of behavioural arousal. This could be said to be similar to the effects found of undernutrition, which has been shown to alter arousal and emotionality, without the detrimental effects of food shortage on body weight.

The total literature in this field covers a wide range of techniques for producing infantile stimulation effects, other than handling; such as shocking, sensory stimulation and injection. The time of application, whether pre- or post-weaning, has also been studied. Typically prenatal stimulation is thought to produce 'bad' effects, on rats but results for other species are not so constant (i.e. Adams, 1975).

In the mouse, as might be anticipated, the effects of the standard handling technique appear highly dependent on the genetic disposition of the specific strain used. This was first demonstrated by King and Eleftheriou (1959) who found that in one subspecies of deermouse handling significantly improved avoidance learning, whilst impairing it in a second subspecies. Similarly, Ginsburg (1960) showed handling to either increase or decrease exploration - the direction of the result being dependent upon strain. Daly (1973) found no evidence that handling leads to a reduction in emotionality as shown by defecation, although he notes several reports on its elevation. Watson, Henry and Haltmeyer (1974) report significant increases in open-field ambulation following handling in CBA mice, although no corresponding change in their plasma corticosterone levels. A shorter latency to fight in handled animals was interpreted by Levine (1959) as indicative of decreased emotionality, although I find little connection between increased aggression and lower emotionality. Indeed, Svare and Leshner (1973) report a positive correlation between aggression and reactivity to a novel environment in Sprague-Dawley mice and Elias and Bell (1975) a significant correlation between activity and aggression in Swiss albino mice. However, Brain and Nowell (1970), using albino laboratory mice, report no relationships between activity, defecation or composite aggression scores, although there does appear to be a positive correlation between these aggression scores and the plasma Na^+ concentration. Several experiments have shown mice to be more sensitive to the level of stimulation used than rats (for example, see Denenberg and Bell, 1960 who used electric shock, and Labarba, Fernandez, White and Stewart, 1974 who used tactile stimulation), in that moderate stimulation results in improved learning and lower emotionality respectively whilst higher levels of stimulation produce impaired results. Overall the results of this species are not really in accord with those found in the rat - indeed when exposed to total food and water deprivation or injection of a dangerous virus the handled mouse is less able to survive than a non-handled mouse, the opposite reaction from that found in the rat, yet both rats and mice belong to the same suborder Myomorpha - as does the golden hamster.

It was in mice that Bell, Nitschke, Gorry and Zachman (1971) first demonstrated the alteration in ultrasonic call emission from the pups as a result of handling; and have shown this emission to vary in accord with the level of stimulation to produce either effective or excessive arousal in the female (see Bell, _et al_, 1974). These changes in arousal lead to significant alteration in the behaviour of the female directed towards the pups, i.e. both Priestnall (1973) and Sherrod, Connor and Meier (1974) have shown increases in maternal attentiveness in CFLP and BALB mice. These effects however, which lead to an increase in maternal stimulation of the pups, are only transient with the long term effect being a disruption in the females' normal activity pattern. Unfortunately neither of these papers reports the effect of the handling procedure on the pups - but it seems that in many ways the female's response serves only to exaggerate the stimulative properties of the procedure itself. The evidence generally indicates that stimulated pups elicit more maternal attention than non-stimulated pups, and it is interesting to note that variation in the ability of pups to elicit stimulation from their dams has been demonstrated for different subspecies of commonly used laboratory mouse (Reading, 1966).

This may be a factor in the variation of handling results obtained in mice. Typically the mediation of the handling effect, as demonstrated in both the rat and the mouse, via maternal behaviour might be expected to have similar results in the two species but it seems that differences in the sensitivity of the pups to levels of stimulation and in the developmental rate lead to the variation of effect - a theory that has some support from Schaeffer (see Ambrose, 1969). Within the order Rodentia results from infantile stimulation are inconsistent; outside that order there is little, if any, comparable data.

The only reported example of handling on a species from another order than Rodentia is given by a series of experiments on the domestic rabbit, which is of the order Lagomorpha, although within the same general classification group (see Appendix Eb). An initial experiment (Anderson, Denenberg and Zarrow, 1972) showed that thirty days of handling resulted in a significant decrease in timidity with consequent increase in exploratory behaviour. In a replication experiment designed to eradicate some poor features of the initial investigation Denenberg, Wyly, Burns and Zarrow (1973) found that two subspecies of rabbit responded to handling by being more active when adult; and one species at least was more exploratory and spent more time near a social stimulus (another rabbit). Moreover these results were obtained independent of maternal interaction as the female will naturally spend the greater part of the day away from the nest. A final experiment showed that this twenty days of handling did not demonstrate a definite critical period for results to be obtained, rather the stimulation appeared to be additive with the second ten days being most effective in producing increased activity and response to novel objects. The increase in sociability was not replicated (Wyly, Denenberg, De Santis, Burns and Zarrow, 1974).

These data were deliberately obtained in order to demonstrate the broad applicability of the handling procedure, as already mentioned. However, due to the fundamental differences in the experimental design and the acknowledged lack of importance of maternal interaction it seems coincidence may be playing a part in producing results.

Finally, an experiment reporting the effects of handling domestic kittens (Wilson, Warren and Abbott, 1965) is worth mentioning as they did find 'daily handling during infancy led to less "fearfulness' in that they approached strange toys and humans more readily and required significantly more trials to learn an active avoidance learning task than unstimulated controls'. The main difficulty in evaluating this experiment is that socialisation towards humans, normally occurring in such a domestic species, may itself be a variable in the experiment.

While possible that there is some general applicability of the handling procedure - the rationale of the techniques is somewhat obscure. Further, the results obtained in a particular instance will be dependent upon many factors including developmental stage, sensitivity to stimuli, and previous experience for the pups and the parent; and that with higher levels of development these factors become increasingly numerous, complex and interactive.

(iii) ISOLATION/DEPRIVATION STUDIES

The effects of isolation as such are rather difficult to state as these are in fact the 'control' conditions of many laboratory experiments. In practice, data for isolate behaviour comes from studies on the differences between animals raised in isolation in a laboratory cage and animals raised in some form of enriched environment. It is usual that these studies concentrate on perceptual and intellectual abilities rather than upon motor skills, although these are often obviously affected. For example, Baron, Antonitis and Schell (1962) reared mice under a glass plate so as to prevent them climbing until maturity. When tested at 4-5 months of age, these mice were much worse at climbing than controls, although this difference eventually disappeared after 4 months of practice. With other animals the loss of a motor skill in youth may be permanent as in the examples for the dog quoted by Scott (1968). This loss of motor skill (to greater or lesser degree) may have some relevance in comparisons of animals reared in different environments when confronted with certain types of learning tasks.

Another problem with this emphasis on intellectual competence is a wish on the part of some researchers to remove any interaction due to differences in emotionality, and so the animals are handled daily to minimise any differences in this respect (see Morgan, 1973). If one is to accord handling the effect of altering emotionality then one is also affecting that animal's learning ability, and results from such experiments can only be viewed with some caution due to the confusion of variables within the experimental design.

Some of the effects of isolation have shown up the importance of the presence of other members of the species to the correct development of the young. These may be termed 'social facilitation' effects and would include such classic examples as the Bruce effect and the Whitten effect (cf. Bruce, 1970). Many of the mechanisms by which these effects are mediated are probably pheromonal although there is also some evidence that they also are dependent upon genotype. In the following paragraphs examples of these phenomena are given.

a) The sex of littermates influences the subsequent maternal behaviour in the Norway rat - it has been shown that unisexually reared females are less efficient biologically. This appears to be a pheromonal effect emphasising the importance of the males' presence and has also been shown in mice and gerbils - it is probably one of the methods by which a colony's population is maintained with a proper sex ratio (Sharpe, 1975).

b) The presence, and the strain, of the male mouse affects the development of the litter with regard to social exploration, and in some cases, aggression (Smith and Simmel, 1977).

c) The exhibition of aggression in both rats and mice - both inter and intra species - is affected by whether it has been witnessed previously in early life. This type of phenomenon, also exhibited by cats, appears to relate intrinsic behaviour with learnt components (see Lore and Flanelly, 1977).

d) It is known that in the rat maternal deprivation (e.g. from day 13) results in a 90% mortality within the litter although the cause of death is not apparent from a post mortem. This high mortality rate may be prevented to a large extent by the presence of another adult animal, either male or female, even if a screen separates the adult from the litter. Touch has been found to be an important variable in producing this effect.

Obviously, then, species have much wider influences at work within their social structures than has generally been credited (particularly amongst the lower mammalian orders) and this fact should be remembered when altering their environments to any extent.

In general it is fairly accepted that isolation leads to: (i) an increase in aggression and/or emotionality; (ii) an increase in activity; (iii) an increase in gregariousness; and (iv) an increase in the size of the adrenal glands (Warren and Ivinskis, 1973; Morgan, 1973; Masur and Struffaldi, 1974).

The problem of the consequences of handling these animals, as already discussed, are apparent in the paper by Morgan whose results for isolate rats are virtually identical to those of handled rats.

Indeed, a study controlled for handling, temperature changes, shock or transportation to a new location reports some contradictory evidence for both defecation and exploration levels (Barrett and Stockholm, 1963).

Walsh, Cummins and Budtz-Olsen, (1973), demonstrate increased body and adrenal weights in isolated rats and suggest that within this typical finding the increased adrenal weight is secondary to increased body weight. Fiala, Snow and Greenough (1977) demonstrate their position by entitling their paper 'Impoverished rats weigh more than enriched rats because they eat more'; and suggest that there is little reason to propose metabolic differences in this species similar to those found in isolate and complexity-group-reared animals, as shown by monkeys, where a fundamental stress reaction is producing the effect. This does appear to be the case as under a 'stressful' condition one would expect an increase in adrenal weight to be associated with a decrease in body weight as shown by Gilbert and Bailey (1969). This has been explained by the adrenal cortex producing secretions which can increase activity, hence causing greater energy utilisation and resulting in overall weight loss - in this case, then, the body weight alteration is secondary to the adrenal weight change (see Richter and Uhlenhuth, 1954). As isolation tends to be associated with increased activity the suggestion that the adrenal changes are secondary to body weight simply due to increased food consumption may appear erroneous; however, the increased activity could result from many factors including extrinsic forces as well as possible results of the increased adrenal size, and secondly, Sackett, Bowman, Meyer, Tripp and Grady (1973), report that isolation is in fact associated with both high and low levels of activity. Support for the view that isolate rats are not under stress comes from the resting levels of plasma corticosterone in these animals, which is slightly more than half that for grouped animals with less daily fluctuations (Barrett and Stockholm, 1963). It must be remembered, that these rats are not maintained in total isolation but simply caged singly.

As early as 1957 Bindra concluded that the most important variable in producing these effects was the age at which the animals were exposed to the condition. This is normally post-weaning; an experiment by Morgan (1975) using earlier isolation (days 17-25) resulted in increased timidity, decreased activity in the open-field, and increased object avoidance. In other words, opposite changes than those obtained with later, and longer, isolation - possibly as a result in part of some of the factors mentioned above. It seems that the social environment of rats determines the central action of corticosterone by modifying the concentration of corticosterone brain receptors - an effect which would have varying results depending on the development of the CNS (Dessi-Fulgheri, Lupo and Valeri, 1975).

This effect of early isolation has also been shown in gerbils (Berg, Shanin and Hull, 1975) who found decreased territorial marking, aggression and open-field activity together with increased adrenal weight. No effect was found on body weight, gonadal function or sociability. They concluded that early isolation disrupted sexual behaviour at maturity, and that visual contact with others was necessary for adult behaviour to appear.

The evidence for alterations in learning ability is relatively clear in that most studies report a rigidity in the behaviour of isolates, with a decreased ability to inhibit irrelevant responses (Morgan, 1973; van Woerden and Raaijmakers, 1975); with the overall impact of the experience being dependent on genetic endowment - as in strains of maze-bright and maze-dull rats (Cooper and Zubeck, 1958). This intuitively appears correct as the isolates have had little occasion in which to learn to be plastic, and conservative, in their behaviour.

In mice, the results again show the importance of length of isolation and the age at onset, with even more emphasis on the interaction with genotype. For example, Anton (1969), using DUB/ICR mice, found no significant differences attributable to the environment although Watson, Henry and Haltmeyer (1974), using CBA mice, found significant changes in social behaviour together with high systolic blood pressure and plasma corticosterone. Most workers report a lower steroid level in isolate mice Brain ,(1972) related to the changes in androgen production which increases, resulting in the widespread finding of greatly increased agonistic behaviour(1).

(1) It is worth noting that changes in gonadal function in the isolate mouse which result in increased agonistic behaviour, heavy ventral postate glands, greater production of androgens and lower levels of plasma glucocorticoids are similar to the effects of dominance in this species; suggesting that submissive animals are 'damped down' within a social context rather than dominance being attained.

Essman (1971) has also shown an increase in locomotor activity which correlates with the concentration and metabolism of brain serotonin, and lowered norepinephrine levels.

(iv) ENRICHED ENVIRONMENTS

Studies on the effects of enriched environments have been carried out almost exclusively in the rat, although examples of the effect of colony living may be found in other rodent species. This emphasises the difficulty in design of experiments which, by their nature, involve both physical and social environmental enrichment. Indeed, there is evidence to suggest that these two interact in producing a social facilitation effect. Rosenzweig, Bennett and Diamond (1972), found brain measures are unaffected if the animals are either grouped in a non-enriched cage or placed singly in a large cage with play objects. Such measures usually show significant differences in overall size, structure detail and metabolism in enriched grouped animals.

Early studies into the effect of a free-environment (i.e. a large enclosure for a group of weaning rats supplied with structural variation and play objects) were inspired by Hebb (1949) and found increases in the adult rats' problem-solving ability (Forgays and Forgays, 1952). The experience was found to be most effective when animals were exposed immediately postweaning (Forgays and Read, 1962), although preweaning experience also brings about a permanent improvement in problem-solving (Denenberg, Woodcock and Rosenberg, 1968). The large majority of studies have been concerned with learning ability changes, and to a lesser degree social behaviours, with little emphasis on the individual animal's behaviour. Evidence suggests that enrichment in fact increases activity and exploratory behaviour whilst decreasing emotionality (Luchins and Forgus, 1955; Denenberg and Morton, 1962, 1964) - all factors which may underlie the improvement in performance of learning tasks, to some extent. These effects are also obtained with the enrichment preweaning (Morton, 1962; Forgays and Read, 1962) so the change in activity and emotionality cannot wholly account for the improved learning as postweaning is more effective than preweaning as already mentioned. In fact the maximum effect from these environments coincides with changes in emotional and investigative behaviour as shown by open-field testing at various ages (Candland and Campbell, 1962). This may have certain parallels with the changes in physiology shown in dogs at various stages of early development (see Scott 1958) and that social responsiveness in cats correlates with increased sensory capacities, independence and mobility (Kolb and Nonneman, 1975).

The major conclusion to draw is that there are direct correlations between the effects produced by an environmental change and the animals apparent stage of development as indicated by structural and behavioural indices - with the timing of the environmental change affecting those systems viable at that time. Typically, it seems that the earlier experiences affect more underlying attributes - such as levels of emotionality - so 'setting' the animal for future reactivity; whilst later experiences can be more specific with the CNS and sensory systems' maturing. For example, a ten-day old rat with its eyes not yet open is unlikely to benefit much from a visually enriched environment that would improve form discrimination in a visually mature animal.

The importance of perceptual learning in infancy, per se, has been stressed and demonstrated many times - for example Gibson and Walk (1956), Gibson, Walk and Tighe (1959) - although, again, prior experience of the stimuli must affect to some extent the reactivity during testing. Some studies suggest that in fact animals within different environments learn to use different cues for problem-solving and that the behavioural differences found are not in fact due to an overall improvement in intelligence. Beach and Jaynes (1954) conclude that although one gets improved Hebb-Williams maze performance in enriched rats due to the increased ability to use visual distance orientation cues (as proposed by Forgays and Forgays, 1952), there is no improvement in simple tasks such as simple alley maze learning or visual discrimination problems where there is no use of such distance cues. (There does appear to be a tendency for enriched animals to do better on more difficult tasks, particularly when there is an element of survival in either the environment or the task itself (see Hübscher, Knüsel, Heidelberger and Kuenzle, 1975). This may be true to a degree but an animal with a wider experience during development is also more able to deal within a novel situation and its behaviour is more plastic - with the added advantage of being able to utilise a greater number of cues.

Physiological measures to correlate with improved cognitive performance, as a result of environmental enrichment, are legion and include increased cerebral length (Altman et al, 1968: Walsh et al, 1971); increased cerebral cortex weights (Ferchmin et al, 1975); increased DNA polymerase activity in brain neuronal nuclei (Hübscher et al, 1975); changes in cortically-evoked brain potentials (Mailloux et al, 1974) and many changes in brain bio-chemistry (see Rosenzweig et al, 1968). However, many of these measures are only readily observable following long periods of enrighment - for example, increased cerebral length is a well-documented consequence of enrichment for 80-90 days but shorter periods (i.e. 30 days - more in line with that required for early experience studies,) give unclear results. Most reports show no significant increase in length for 30 days (Walsh et al, 1971); although another report (Walsh et al, 1973) states that 30 days significantly increases the cerebral length to within 50% of that found in rats enriched for 80 days. This difference may be explained by some variation in technique - and again demonstrates the difficulty of drawing adequate conclusions from studies which vary so wildly in their design.

Whilst there is this considerable body of evidence to suggest that 'enriched environments' have the effect (especially in the immeadiate postweaning period) of improving problem solving ability and decreasing emotionality it is by no means clear how these should be evaluated. The studies range from gross privation studies (such as those of Melzack and Thompson with dogs) to those in which laboratory rats are reared in quasi-natural environments of substantial size - often, however, 'enrichment' may amount to no more than rearing the laboratory rat in cages ½metre square, possibly with a few moveable objects in the cage. The difficulty arises over what may properly be called 'enrichment' and what 'privation'. Almost any animal in its natural habitat would experience an environment more varied and complex than that provided by the standard laboratory rat cage; it would also enjoy a much greater freedom to control its social environment in that it could select or avoid its conspecifics. Whether we should look at'enrichment studies' as attempts to reduce the gross privation of the small wire cage, or whether the enrichment studies are better seen as attempts to select critical variables (which might be features of a free-living animals environment) which produce specific changes in problem solving capacity or brain function is quite unclear. 'Enrichment', then, is a loosely used term, the social and physical variables are all too often confounded and, in general, the results suggest that almost any addition to the space available to a growing (or even mature) rat or the variety of objects it encounters has a generally favourable effect.

It is even more difficult to determine what are the mediating effects - whether it is the different behaviour induced in the animal that is critical or the actual stimuli themselves (although Luchins, Forgus and others favour the former hypothesis) it could well be that rats reared in large cages find the open-field, for example, less 'open' than rats reared in smaller cages and hence respond to it differently for this reason alone.

Few, if any, studies have carried the notion of enrichment as far as to allow the subjects to become essentially feral (surely the ultimate enrichment) and it is not at all clear that such a 'natural' environment, which would necessarily include many hazards as well as a gross increase in complexity, would produce any of the same effects as rather larger cages with more features than the standard laboratory cages which are used to keep laboratory rats, at least, in good health. Rats breed freely and grow well in a minimum of space which is why they are so well adapted to the laboratory - such small cages make no demands on them and often provides few opportunities for learning. The laboratory environment is, in addition, usually extremely monotonous and predictable. Against this background it is obvious that almost any 'enrichment' will have behavioural consequences. Whether the work with dogs and monkeys can be seen in the same way seems doubtful as neither species are normally bred or reared in conditions of such extreme restrictions, or genetically selected (as laboratory rats have been) to tolerate such conditions well. In these circumstances any cross-species comparisons, let alone inferences, are difficult and the effect of 'enrichment' on the laboratory rat is best considered at present as a separate phenomenon.

Even so, existing work provides few valid comparisons because of the very diverse experimental strategies which have been grouped together as environmental studies. The safe conclusion is that space, complexity and social facilitation have all been shown to affect behaviour in at least some strains of rat, and beyond that a great deal remains to be discovered and elucidated.

When assessing the overall results of early experience studies it is difficult to know what to make of the conflicting reports in experiments using mice. The mouse has proved a useful experimental animal in the laboratory not because it is readily modified by experience but rather because of its genetic lability. Among the many pure strains of laboratory stock a remarkable variety of mutations have emerged and been preserved, many of which display phynological anomalies which are often associated with concommitant behavioural variation.

By contrast laboratory rats of different strains are much less variable, although (as already indicated) laboratory stock differs in many notable respects from wild stock (whether free-living, trapped or laboratory-bred) especially with respect to 'tameness' and adrenal function. The rat has shown a remarkable capacity to adapt to the laboratory environment without the dramatic genetic variation shown by the mouse. It has also been the species of choice for a multitude of psychological studies because of its capacity for learning and for behavioural modification when under the influence of environmental factors. This choice of species as the main subject in the field of early experience has allowed failures in replication of effect to be ascribed to variation in experimental technique rather than genetic susceptibility. However, it has also led many authors to assume that the rat is a good model for early experience work and hence to suggest that phenomena demonstrated with this species are likely to have a wide order of generality. While few have gone as far as Levine (1962b) in suggesting that the results are immediately applicable to man, these effects are at least tacitly supposed to have a fairly high order of generality, so that like phenomena might reasonably be expected in other species. In fact, few systematic attempts have been made to test this assumption and it is rather the choice of the rat as subject species which has led to this erroneous conclusion - it may well be rather that the response of the rat to early experiences is the reason it has succeeded so well as a laboratory species.

Although, as has been suggested earlier in this introduction, variations in physiological process do not always follow the lines of taxonomy generally accepted, the simplest assumption is that the dramatic effects of early handling and similar phenomena would hold true within the order Rodentia at least. One purpose of this study was therefore to test the validity of such an assumption specifically using the golden hamster. The hamster is in some ways rather remotely related to the Norway rat but is, within the general taxonomy of mammals, a member of the same suborder. If, in hamsters, roughly the same patterns of behavioural sequelae follow early handling and environmental manipulation then the assumption that generalisations within an order or suborder are valid would be greatly strengthened. Further, the assumption that what is true for 'rodents' may be true for the whole mammalian class would be more sufficiently tenable and a serious, systematic search for supporting evidence of a general principle might be initiated which might eventually perhaps justify an application in human psychology.

If, on the other hand, systematic replication fails to confirm in the hamster those findings so amply documented in the rat, then considerable caution in making generalised assumptions would be proper. It could be that the production of 'early experience' phenomena (i.e. alteration in adrenal stress response in adult life due to early handling) is related to adrenal type and function or social organisation rather than following conventional taxonomic relations which are independent of such factors. Since the hamster and rat adrenal systems are different, conflicting findings may be elucidated by extending the line of enquiry into species with comparable adrenal physiology.

However, by simplest hypothesis is that the rat and the hamster will show a similar pattern of response to manipulation of the early environment and it is this which is tested here. Strain differences exist in all laboratory rodents, but the use of a first cross (F_1) between stock of two pure-bred varieties from different sources not only produces animals of a typical 'wild' agauti coat-type but also sufficiently genetically varied to ensure that the effects observed are not attributable to some atypical recessive character preserved in a pure line or closed stock. The gene pool among laboratory hamsters is in any case restricted due to their history (see previous chapter), and also the laboratory animals appear to differ so little from the wild variety that none of the problems associated with the use of mice as a comparison species should present themselves.

In overall terms, this study is an attempt to test the generality of the findings that in rats early experience in general and early handling in particular has predictable consequences in adult physiology and behaviour by a systematic replication of the commonly used strategies with another member of the same suborder. The hypotheses under test are more precisely defined in the appropriate sections which follow.

V. EXPERIMENTAL CONDITIONS AND METHODOLOGY

V. EXPERIMENTAL CONDITIONS AND METHODOLOGY

Since all the studies reported in this thesis follow the same procedure with regard to general methodology, this chapter details those procedures together with details on the experimental conditions and the testing techniques utilised.

Independent Variables

GENERAL MAINTENANCE

i) Subjects -

All subjects were an F_1 cross-bred, as required, in the department of psychology, Bedford College, from commercially obtained pure-bred agouti (M & B golden) and black-eared cream stock to produce hybrid vigour and heterozygosity. (For further information about genetically controlled characteristics see Lawlor, 1956; Robinson, 1958; and Keeler, 1947). Females of both types were bred with males of the different stock, and assigned at random to one of the experimental conditions. In almost all cases these were naive stock with no previous reproductive or maternal experience. Three litters were assigned to each experimental condition and the actual numbers of animals used are given in Tables 10a,b and c. No attempt was made to control for litter size.

ii) Housing and Feeding -

After mating, females were housed singly in stainless steel maternity cages (16cm x 35cm x 40cm) in the breeding room of the animal laboratory. At least 3 days before parturition these cages were placed in the appropriate preweaning experimental condition where they remained until the litters were aged 21 days. The pups were then weaned and - unless assigned to the 'desert' postweaning condition - were housed in standard white plastic laboratory cages with wire mesh tops holding food and water racks (12cm x 25cm x 40 cm or 18cm x 32cm x 48cm - depending on litter size). At 6 weeks all litters were sexed and caged according to sex and litter in standard cages, maintained in the main room of the animal laboratory. This timing of weaning and separation is thought to be comparable with what would occur under natural conditions (see Rowell, 1961a).

The animal room was maintained at a constant temperature of 21 degrees C on natural supplemented daylight. The breeding room was maintained at the same temperature but had a lower noise level and a 12L:12D artificial light cycle.

Cages were provided with wood shavings and hay as bedding material - pregnant females were provided with extra bedding.

Table 10a: Total Number of subjects used

Condition		Female	Male	Total No. Ss
Burrow-Lab		9	12	21
Lab - Lab		15	11	26
Lab - Desert		14	13	27
Burrow - Desert		13	7	20
H_{0-21}		13	16	29
H_{5-21}		12	12	24
H_{0-4}		13	13	26
NH		15	6	21
	Σ	104	90	194

Table 10b: Total Number of animals used in physiological sample

Condition		Female	Male	Total No. Ss
B - L		6	5	11
L - L		6	7	13
L - D		5	5	10
B - D		4	2	6
H_{0-21}		8	8	16
H_{5-21}		5	5	10
H_{0-4}		5	5	10
NH		6	2	8
	Σ	45	39	84

Table 10c: Size of groups and litters used

Condition	Litter	No. F.	No. M.	Total No.
B-L	175	3	3	6
	176	3	5	8
	188	3	4	7
L-L	179	4	5	9
	180	2	2	4
	191	9	4	13
L-D	190	6	3	9
	177	3	5	8
	194	5	5	10
B-D	189	1	3	4
	193	6	2	8
	207	6	2	8
H_{0-21}	184	2	7	9
	185	5	6	11
	186	6	3	9
H_{5-21}	181	3	3	6
	187	4	5	9
	195	5	4	9
H_{0-4}	198	7	5	12
	205	6	5	11
	206	0	3	3
NH	199	6	4	10
	200	9	2	11

All cages were cleaned out weekly after weaning, with handling being kept to a minimum at all times.

All stock were fed ad lib hamster diet (Styles hamster diet) with water constantly available, and daily feeding of fresh chopped carrot.

EXPERIMENTAL CONDITIONS

These conditions were developed and used to give the basic conditions already discussed (see Chapters 2 and 3), as being determined by the variables under investigation: namely - a handling technique, an early quiet environment (burrow), a standard laboratory (lab) and an enriched postweaning environment (desert). All litters were assigned at random to a condition once the female was mated and found to be pregnant. Throughout the running of the research subjective behavioural observations were made on the experimental animals until maturity. The only objective behavioural observations undertaken were on the maternal behaviour in the preweaning conditions burrow and lab. Earlier evidence had suggested better nest-building in the burrow condition and this was taken to indicate a variation in maternal care within the conditions. To study this a continual video time-lapse recording was made (for 21 days) of one litter in each of these preweaning conditions. The time scale was 48 hours:1 hour, and this was later crudely analysed for amount of time spent off the nest by the female and the number of times of leaving the nest.* All conditions were maintained at a constant temperature of 21-24 degrees C. In all conditions handling was minimal, with the animals being disturbed as little as possible, apart from the daily feeding of carrot and absolutely essential cleaning.

i) Handling -

This technique described here had already been used in this department (Lawlor, Wells and Weinberg, 1975) and is satisfactory for use with hamsters with minimum loss of maternal care and cannibalism, which has often been reported previously for this species.

The litters were normally born during the afternoon - the earliest at 2.00 p.m. - so that day of birth was designated as day 0 and animals were not handled on that day. Handling was carried out at approximately 11.00 a.m. daily, this being a time of day when the female is least reactive. To prevent anxiety on behalf of the females

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* All of these behavioural observations are detailed in appendix A.

during handling, small pieces of dog biscuit were scattered in the cage on the opposite side from the nest and an aluminium barrier put across the cage between the female and the litter.

For handling, a new pair of clean disposable surgical gloves were worn (and changed after each litter had been handled) and each pup was removed individually from the nest by hand and placed in a plastic cup (9cm diameter, 16.5cm height). Small green cups (5.5cm diameter, 3.5cm height) were used on day 1 but after this it was found the pups could readily climb out so the larger cups had to be used. When all the pups had been placed in the cups they were then transferred back to the nest in the same manner and order in which they had been removed. When they were all back in the nest the barrier was removed and the female allowed free access to the litter. The whole handling process took from 3-5 minutes per litter. No cup was used more than once a day and they were all well washed in disinfectant detergent before being reused. At no time were the pups in contact with anything that could leave a residual, strange scent. In the handling experiment litters were assigned to the different conditions (i.e. handled days 0-21, H0-21, handled days 0-4, H0-4; handled days 5-21, H5-21) at random and only handled on those days. In the NH (i.e. non-handled) condition everything was carried out exactly the same without actually handling the pups - i.e. the cage was removed from the rack and the top removed; the female was enticed from the nest by dog biscuit and separated thus from her litter for several minutes; the barrier was then removed, the cage top replaced and the cage returned to the rack.

ii) Burrow -

This condition was set up in a small semi-soundproofed test room close to the main animal laboratory. The room was blacked out and illumination provided by a 6-8W night light, pointed at the ceiling, on a 12L:12D schedule. The level of illumination in this room was 0-0.4 lumens/sq.ft. There were usually only 3 cages in this room at a time, although they were always females they were not always with litters and no males were ever present. The night light was replaced with a 100W bulb during the last day of this condition before weaning to accustom the pups to a brighter light level. This condition was a preweaning condition for animals aged 0-3 weeks, and provided a very quiet, semi-dark early environment.

iii) Lab -

Standard laboratory conditions were a constant temperature of 21-24 degrees C; a 12L:12D artificial light cycle prior to weaning, then supplemented natural daylight, giving a level of illumination of 2-10 lumens/sq.ft.; and a much greater variation in noise levels than the other conditions. The social environment was also much richer here due to the presence of hamsters of both sexes and all ages, and also the presence of other species - namely mice, monkeys and people. —

iv) Desert -

This was a postweaning enrichment environment for animals aged 3-6 weeks. The environment was constructed of wood (1.3cm ply), lined with planika (a plastic laminate), measuring 118cm x 130cm with walls 38cm high. Food and water bottles were supplied in racks screwed to two sides of the environment (see plates 1 - 3) at such a height that the young pups could easily reach them. A hinged clear perspex lid was placed on top with large ventilation holes. The environment contained two metal nest boxes - one square (14.5cm x 14.5cm x 17.5cm) and the other round (diameter 14.5cm x height 17.5cm). These had hardboard or dark blue plexiglass tops weighted with bricks and were set in two adjacent corners. There was abundant wood chip, hay and food provided and various objects as listed in Appendix C.

Lighting was provided by two fluorescent strip lights (65/80w), which hung over the environment at a height of 128 cms above the floor. This provided an illumination level of 52 lumens/sq.ft. on a 12L:12D schedule. The room in which the enriched environment was situated was rarely used except for reason of this research - so the immediate noise level and intrusion factor is low. However it was by a busy corridor with plenty of background noise (e.g. lift). There were usually two enriched environments in the room, together with 2-4 cages containing other postweaning litters. Mature animals were not present .

Dependent Variables

PHYSIOLOGICAL MEASURES

i) Body Weight -

All litters were weighed at weaning to obtain the mean pup weight, and when mature they were weighed individually before and after the open-field testing. Animals were then weighed at approximately 3 months and occasionally thereafter if they had not been used in physiological analysis.

ii) Organ Analysis -

When aged approximately 3 months a sample of at least five males and five females were taken from each condition (none of which had been used in discrimination learning). These animals were sacrificed by stunning and rapid decapitation to obtain a normal blood sample. Brains, with optic tracts, brain stem and cerebellum removed, and adrenal glands were removed from each animal, weighed using an electric

Plate 1: Overall view of enriched environment (desert condition).

Plate 2a: Round nest box in enriched environment (top on).

Plate 2b: Round nest box in enriched environment (top off).

Plate 2c: Square nest box in enriched environment (top on).

Plate 2d: Square nest box in enriched environment (top off).

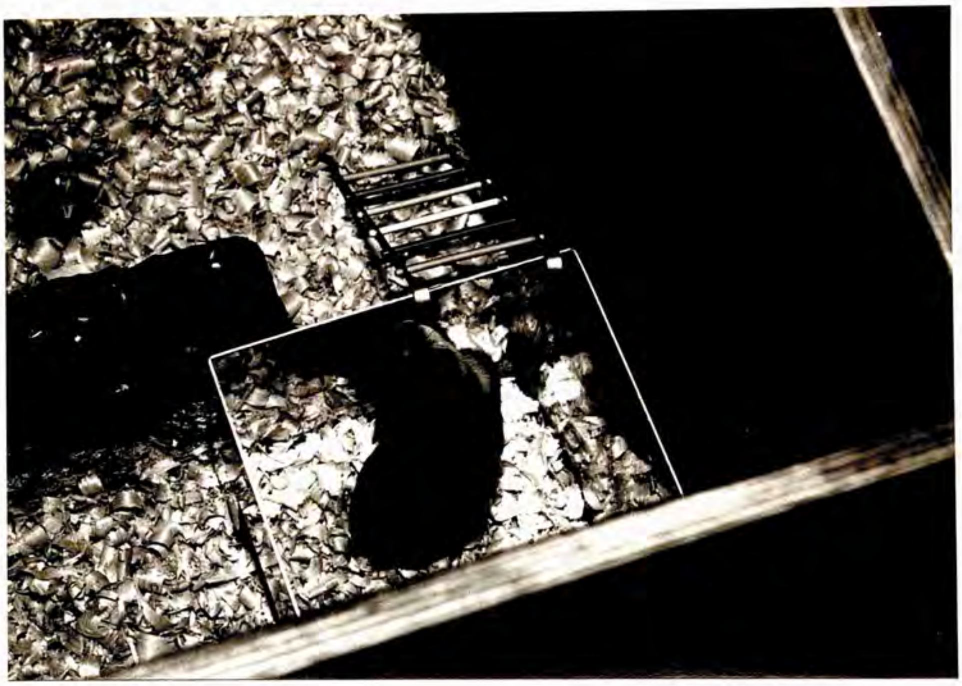


Plate 2e: Animal in square nest box in enriched environment.

Plate 2f: Animal at square nest box in enriched environment.

Plate 3a: Food and water racks in enriched environment.

Plate 3b: Animals at food rack in enriched environment.

Plate 3c: Animals in enriched environment.

balance and then preserved in 10% formal saline solution for later histological examination.

iii) Cortisol Analysis -

A blood sample of at least 1.5 - 2.0 mls. was obtained from each animal in order to perform analysis for resting plasma cortisol level as a stress indicator. The blood was collected in a chilled heparinised beaker and transferred to a chilled test tube for separation by centrifugation at 3000 rpm for 10 minutes. The plasma was then pipetted out, using a fresh pipette for each sample, and frozen within 30 minutes of blood collection in plastic plasma tubes. Cortisol estimation was obtained using a modification of Murphy's competitive protein binding assay - this is a radioactive displacement analysis method which utilises the specific cortisol binding globulin present in plasma. Although this method (described in Appendix D in full) is relatively simple it is fairly specific. This analysis was carried out under the supervision of the Physiology Department, Bedford College with the advice of Prof. Brookes from St. Thomas's Hospital, where the assay was performed.

BEHAVIOURAL TESTING PROCEDURES

All apparatus was washed thoroughly with Tego solution (an odour-destroying disinfectant) both before and after use with each animal. This is an important precaution due to the importance of the olfactory sense in this, as with many, nocturnal species (see Durup, 1965 and other references concerning odour sensitivity and marking behaviour such as Payne, 1979b). All testing occurred within a constantly maintained blacked-out test room with the room lights switched off. Subjects were always handled with a plastic cup in order to minimize handling and distress of subject (see Sykes, 1962). All subjects were used in open-field and novelty testing, whilst the other testing procedures were carried out with samples only.

i) Open-Field Testing -

The open-field is an experimental testing procedure designed by Hall (1934) to evaluate emotionality in a test animal and is widely used by many experimenters as a 'base' measure. This test used Broadhurst's (1960) restandardisation of Hall's open-field which has been shown by Swanson (1966) to give standard, replicable responses in the golden hamster.

This was the first test after maturity, occurring at 45-50 days, and the animals were tested for four consecutive days (see Whimbey and Denenberg, 1967). Males were always tested in the early afternoon whilst females were tested later in the afternoon to avoid sex differences appearing due to time of testing (Lawlor, unpubl. data).
Apparatus: A small circular field (diameter 82 cms) was used, constructed of aluminium walls (height 30.5cm) with white painted hardboard base (92cm sq.), marked off in 19 equal sections with black painted lines, so forming 3 concentric circles in the ratio 1:6:12. The field was illuminated with two overhead 100W light bulbs providing an illumination level of 120-140 lumens/sq. foot (see plate 4).

Procedure: Each subject was taken individually from the home cage using a plastic cup to handle and introduced to the field for a 2 minute test period. The automatic resetting timer was started and ambulation and rearing scores taken. At the end of each subjects' first trial the animal was removed from the field with the plastic cup and marked with red eosin dye in alcohol solution to allow individual recognition before being placed in the spare cage. The scores were noted along with any other behaviours that had occurred. When all animals within a cage had been tested they were returned to the home cage from the spare cage and then replaced in the main laboratory.

ii) Novelty Testing -

This procedure has been successfully used in this department to differentiate between handled and non-handled rats (Wells, 1975). It is an earlier technique developed by Berlyne (1955) and differs from the standard Berlyne box in using a free-standing three-dimensional object, allowing manipulation and other contacts with the subject to occur rather than simple visual inspection. All animals were tested when approximately 60 days of age. Although there is no strong evidence for any sex difference in time of day of testing, it was decided that males would be tested during the morning and females during the afternoon.

Apparatus: The novelty box consists of a metal-sided box (length 40cm, width 26.5cm and height 23cm) with a wooden base (43.5 cm x 28cm x 1.75cm) which was covered in black plastic material, to facilitate cleaning, marked into four equal sections. The whole box was covered with a lid of clear perspex hinged at the back (see Plate 5). Illumination was provided by a single 100W bulb overhead, giving a light level of 100 lumens/sq. foot.

Plate 4: Open-field Apparatus.

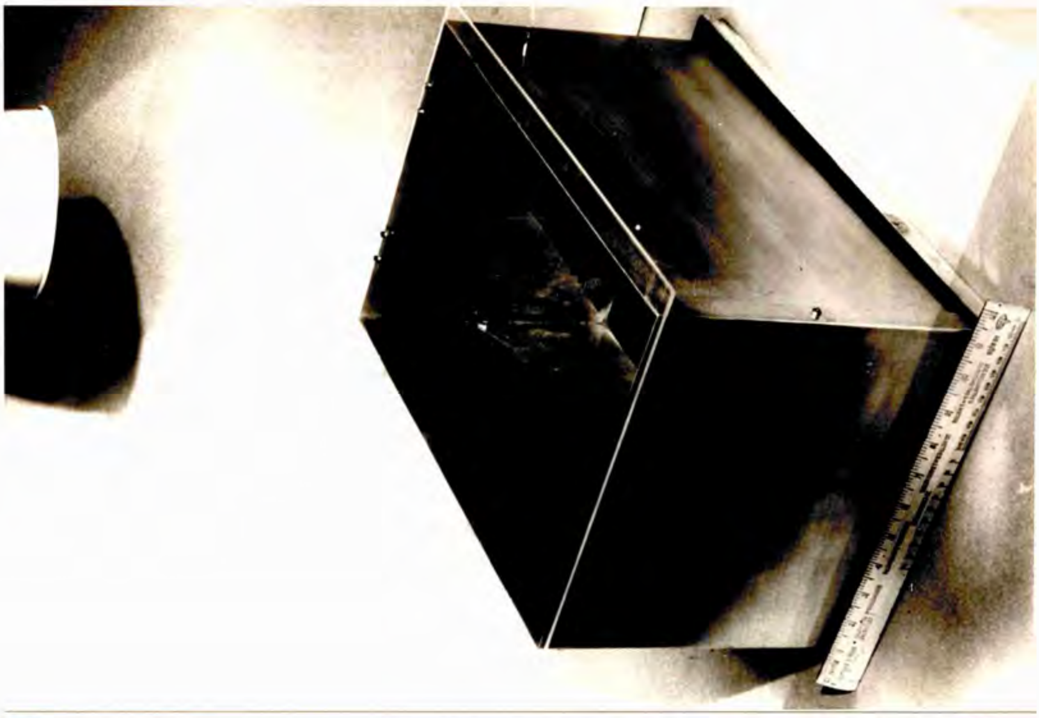


Plate 5a: Novelty box (external view).

Plate 5b: Novelty box (view of interior with novel objects).

The novel objects consisted of two wooden cubes (2 cm) and one cardboard hoop (diameter 4cm, height 1.5cm) for each animal.

Procedure: Each subject was introduced into the front left-hand square of the box from the home cage, using a plastic cup as described for the open-field. The total test period was 6 minutes which was subdivided as follows -

a) During the first 2 minutes testing the subject was allowed to adapt to the experimental situation, ambulation only being scored.
b) At the beginning of the second 2-minute period the box was opened and two wooden cubes (object 1) were placed in the box at the end nearest the experimenter, equidistant from the sides of the box and each other; the box was then closed. The subjects latency to approach either cube (reaction time, R/T) and the total contact time (time on object, T/O) during this period were recorded. 'Contact' was defined as either immediate proximity of subject's nose, together with rhythmic movements of the vibrissae, or as touching or manipulation of the objects with forepaws or teeth.
c) For the final 2 minutes of the test period a cardboard hoop was introduced and placed between the two wooden cubes. The subject's R/T and T/O were then scored for the hoop alone.

On completion of the total test period the subject was removed with the plastic mug and placed in a spare cage; a record was made of the scores obtained and of any other behaviours observed. When all cagemates had been tested they were returned to their home cage and replaced in the main laboratory.

iii) Discrimination Learning -

The apparatus used in this test for brightness discrimination was a modification of Fields Serial Multiple Visual Discrimination Apparatus (SMVDA) (Fields,1953) which had been successfully used by Sykes (1962) to show this, and more complex discrimination problem solving, in the golden hamster. It gives an experimental situation in which the animals exploratory drive provides sufficient motivation for learning to occur, and, coupled with an almost exclusive focusing of the subject's attention on the problem at hand, allows a maximisation of the subject's capacity and motivation to produce rapid learning. The simple black-white discrimination was used to provide a relatively quick testing schedule and was considered sufficiently difficult from previous results (see Lawlor <u>et al</u>, 1975) to give some differentiation amongst the various experimental conditions.

Apparatus: The SMVDA was constructed of hardboard and consisted of five equidistant five-choice panels across a runway, which led to a large goal-box containing toys, wood chip and a few peanuts (See Plate 6 and figure 1). The apparatus was lit by two 100W anglepoise lamps positioned so that the reward area had a lower level of illumination than the choice boxes, and so that the choice panels themselves were brightly lit. The whole inside of the apparatus was painted matt black.

Each choice panel contained five doors (see figures 2 and 3) which open from one choice box to the next at ground level. These doors were hinged at the top so that they were opened by a push from the approach side; and they were locked shut by means of a bar at one side of the door which dropped across the back of the door into a retaining cup-hook on the opposite side. This locking bar was hidden from the approach side by a baton of wood fixed across the back of the door so that one could not tell which door was locked (see figure 3). On the front of each door was a slide holder to hold the stimulus cards, and to allow easy insertion and removal.

Procedure: The object was to construct learning curves for subjects from different experimental conditions on a simple brightness discrimination using white stimulus cards (4 cm x 6 cm) as positive stimuli and the black door with no card as a negative stimulus. Due to the constraints of time, only 3 males, approximately 100 days of age, were selected from each condition for this test - 3 litter-mates being used and caged together.

Adaptation to apparatus: Each cage of subjects was given 2 sets of pretrials, with 3 trials per set, which was found to be enough training to get animals running through the apparatus within one minute - the criterion to reach before attempting any learning. This minimisation of pretrials also prevented the animals from getting over-stimulated with the situation - one of the advantages of this apparatus being that in every trial the animal must make five responses (1 for each panel) to attain the goal box. All doors were given positive white stimulus cards and, starting with the doors fully open, on each pretrial the doors were gradually shut down until they were fully shut and the animals were quite capable of pushing them open without distress. After each pretrial the animals were given 1 minute in the goal box. It had been found that subjects learnt to go through the doors sooner if they were with other animals of the group -

Plate 6a: Single panel of [illegible], rear view.

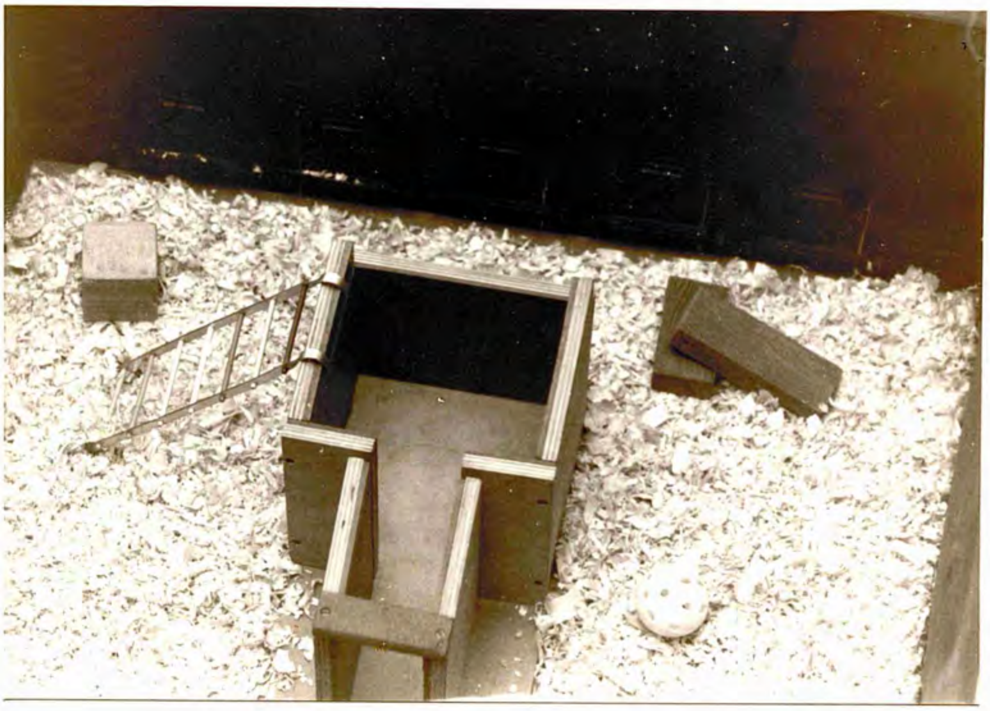


Plate 6b: Goal area of [illegible].

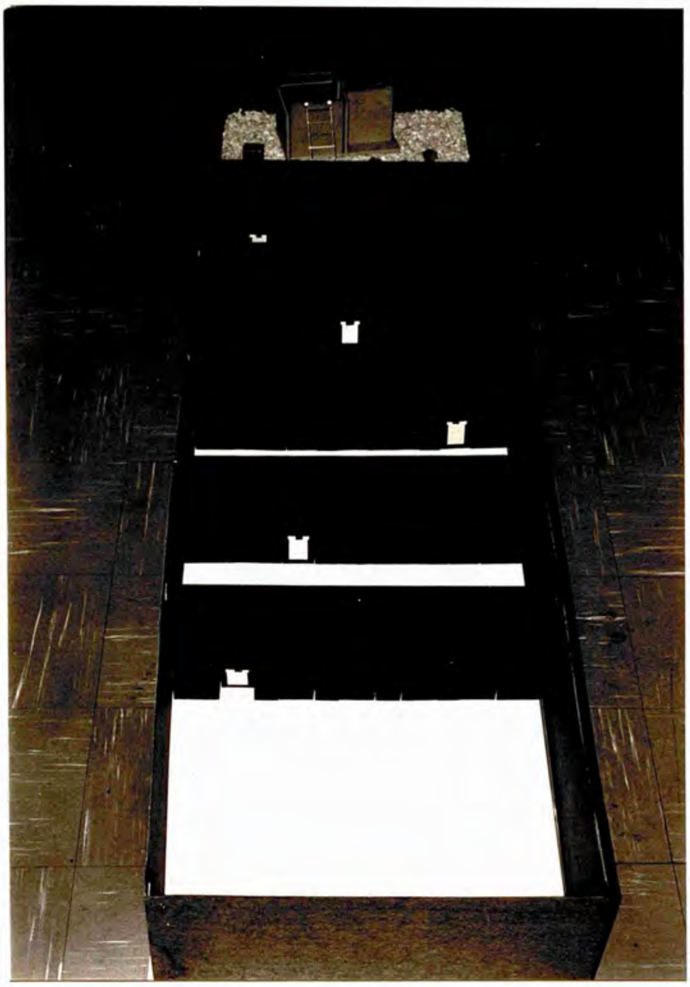


Plate 6c: Overall view of [illegible].

Figure 1. Serial Multiple Visual Discrimination Apparatus (SMVDA): diagram of choice boxes and goal box with dimensions.

Figure 1

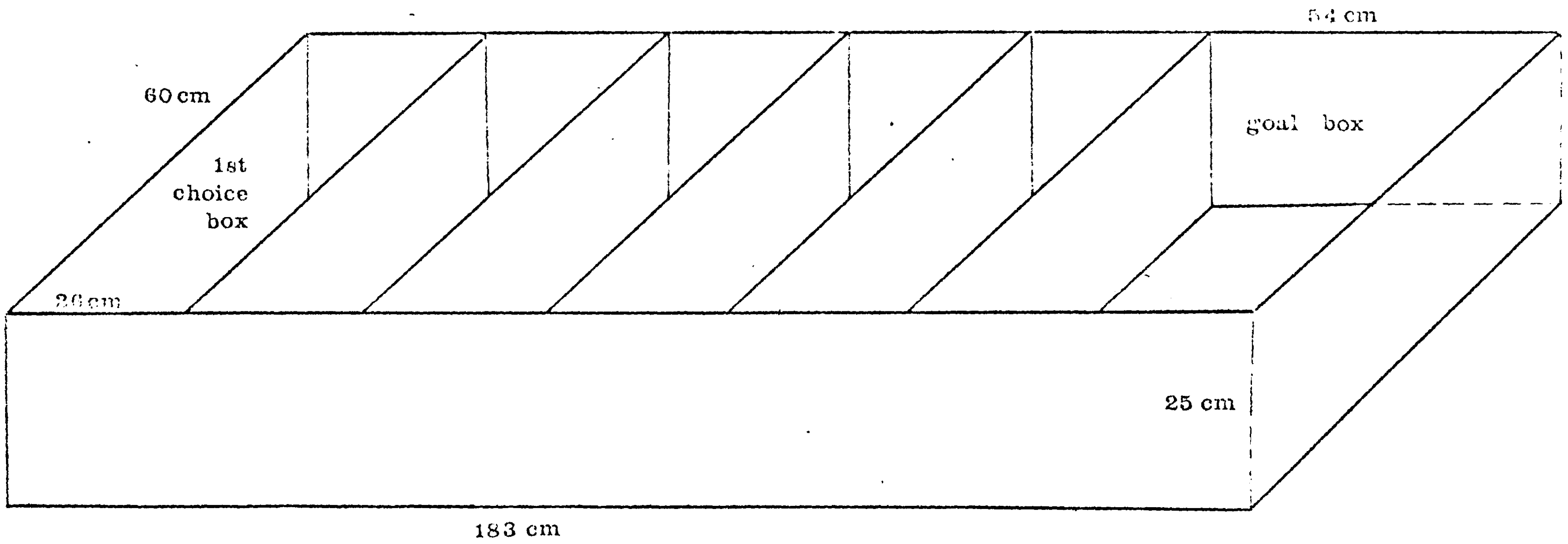


Figure 2. SMVDA: single choice panel (front view)

Figure 2

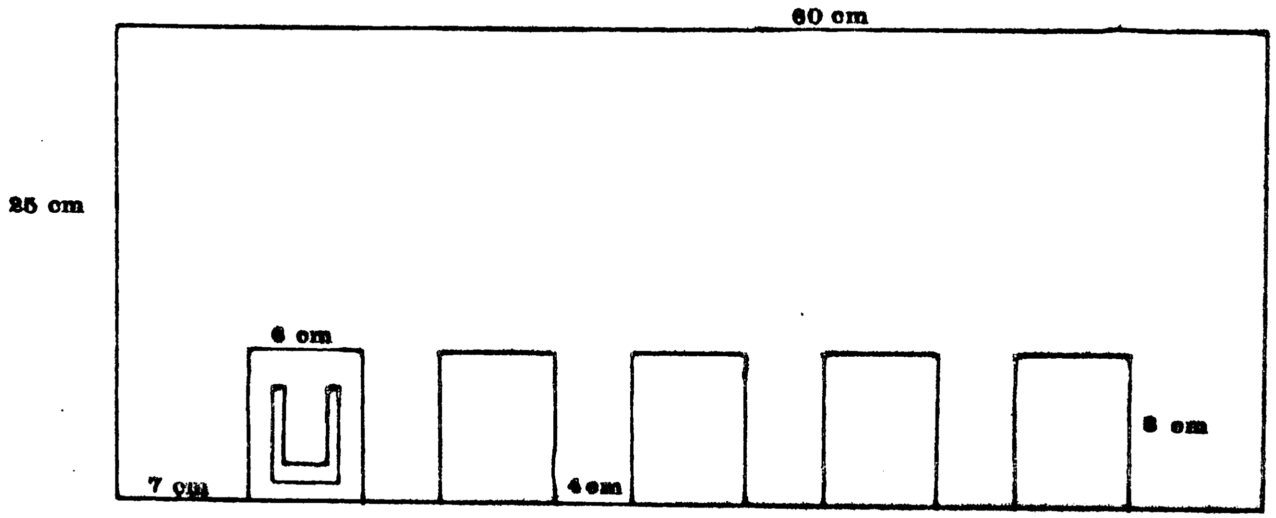


Figure 3. SMVDA: rear view detail of single door

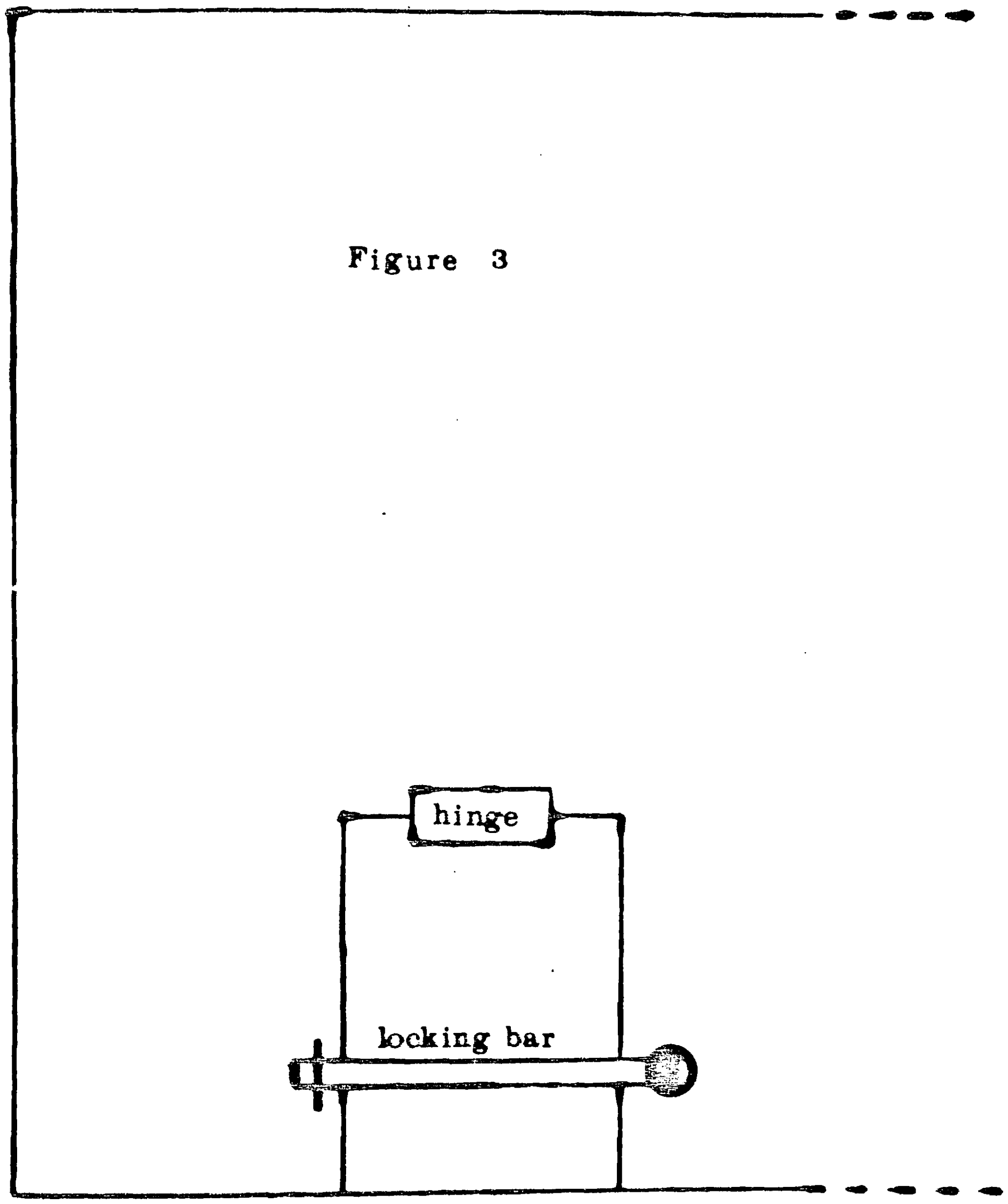


Figure 3

Scale : 0·1 in represents 1 cm

Therefore all 3 males from any particular condition were given their pretrials as a group before going on to individual learning. The two sets of pretrials were normally given on two consecutive days, and then there followed learning trials on the following four days.

Learning trials: One door in each panel was randomly assigned for each trial to be positive, i.e. it had a white stimulus card, and all other doors were locked; all doors being in the shut position. On the first trial of day 1 all the doors on the first panel were assigned positive. Each subject was taken from its home cage in the test room using a plastic cup and placed in the apparatus individually. The number of correct responses (the number of panels for which the animal selected the white door without attempting any other door on that panel) and the time taken for each trial was noted, each animal being given 1 minute in the goal box before being placed in a spare cage. The remaining two subjects were then each given a trial before the second trial of the day was begun. All subjects had a total of four trials (i.e. 20 choices) for four days to determine their simple learning ability.

All testing procedures were analysed using analysis of variance, with litter means being used where appropriate. In some cases a harmonic mean had to be used due to uneven sample size in the physiological data, for statistical reference see Winer (1962). In certain cases, 10% levels of significance are quoted although this is not standard practice. It was felt here, due to the few degrees of freedom and stringency of the statistical tests, that such an action was appropriate - at least in indicating possible areas of effect. In view of the size of many of the F ratios it would have been more inappropriate to accept the null hypothesis than to reject it. The best one can do in these circumstances is to indicate (by noting the 10% level of significance) which variables accounted for most of the variance and leave it to further research to clarify the issue.'

VI EXPERIMENTAL RESULTS

SECTION 1: Pilot study into effects of an enriched environment in the golden hamster.

SECTION 1: Pilot study into effects of an enriched environment in the golden hamster

Introduction

As stated in the text of this thesis no study has been carried out into the effects of a free enriched environment in the golden hamster, although the effects of such an independent variable in, for example, the laboratory rat are well-documented (see Denenberg, 1972). Typically these studies have concentrated on changes in cognitive ability with a tendency for an improvement in problem-solving ability, accompanied by changes in brain physiology, as a result of enrichment (Forgays and Read, 1962; Rosenzweig, Bennett and Diamond, 1972). More generally, there seems to be an increase in activity and exploration with an accompanying decrease in emotionality - all factors which may well underlie the improvements in cognition. Although much of the literature is concerned with the effects of enrichment experienced prior to maturity this study was conducted using mature animals available in the department.

Experimental design and methodology

INDEPENDENT VARIABLES

i) General Maintenance

(a) Subjects: Six pairs (3 pairs of each sex) of mature hamsters (Wright strain, aged 14 months) were used. These animals had been received, as pairs, in the department when aged 8 - 10 weeks and had a known experimental history. Two pairs of each sex were used as controls, with one pair of each sex experiencing the enriched environment. One control male died of natural causes during the course of the experiment and he has been omitted from the results data.

(b) Housing and Feeding: Animals were caged in standard white plastic laboratory cages (12 cm x 25cm x 40cm) with wire mesh tops holding food and water racks. Both the animal room and the experimental room were maintained at a constant temperature of 21-24 degrees C on natural supplemented daylight, to provide a 12L:12D light cycle. Cages were provided with wood shavings and hay as bedding material, and were cleaned out weekly. All stock were fed ad lib hamster diet with water constantly available, and fresh chopped carrot was provided daily.

ii) Experimental Conditions

The two experimental conditions consisted of the standard laboratory condition (described above) and the enriched environment condition. The enriched environment consisted of a planika-lined wooden enclosure (118 cm x 130 cm) with 38cm high walls. The floor was wooden and covered with wood chip - hay also being provided for bedding. A hinged clear perspex lid was placed on top with large ventilation holes. The environment contained two metal nest boxes - one square (14.5 cm x 14.5cm x 17.5cm) and the other round (diameter 14.5cm x height 17.5cm). These had hardboard or dark blue plexiglass tops weighted with bricks and were set in two adjacent corners. Food, provided ad lib, and water bottles were supplied in racks screwed to two sides of the enclosure and fresh carrot was fed daily. Various objects, as listed in Appendix C, were also provided. (This is the same environment as that used for the desert postweaning condition in the main research - for further detail see pages 121-124).

The experimental subjects were placed in this environment for 3 weeks, with the control subjects in the same room, thus minimising external environmental differences between the groups.

DEPENDENT VARIABLES

i) Body Weight

All animals were weighed immediately before being placed in the experimental room, and were then reweighed after 21 days. These animals had also been weighed 24 days previously so providing data for normally expected growth during the experimental period.

ii) Open-field Testing

This standard testing procedure was carried out using a small circular open-field (diameter 82cm), constructed of aluminium walls (height 30.5cm) with a white painted hardboard base, marked off into 19 roughly equal sections with black painted lines to form three concentric circles in the ratio 1:6:12. Testing was carried out in an open room under conditions of natural daylight. All animals were tested before being placed in the experimental conditions and again immediately after removal from that condition, before being returned to the animal room.

The procedure for testing was constant for each animal: each subject was taken individually from the home cage using a handler(1) and introduced to the field. Latency to emerge from the handler was recorded and the animal observed in the field for a 2 minute trial. Ambulation, scoring separately for inner and outer sections, and rearing scores were taken. At the end of the trial the animal was removed from the open-field and, on the pre-experimental trial, marked with red eosin dye in alcohol solution for identification before being placed in a spare cage. When both subjects of a pair had been tested they were returned to their home cage.

Some notes were also made on casual behavioural observation during the experimental period and during open-field testing.

Experimental Results

Data were analysed using a repeated measures analysis of variance with harmonic mean. A simple examination of the data was also carried out using the Mann-Whitney U-test on discrepancy scores (i.e. the difference between pre- and post-experimental values) for the two experimental conditions.

BEHAVIOURAL OBSERVATIONS

These observations were made casually on the animals in the enriched environment during routine inspection and cleaning. No overall preference was found for the square or the round nest box in the environment although initially both experimental pairs had only used the round box. The males built better nests and hoarded less than the females.

In each pair it was apparent that one animal was dominant and the other subordinate. In the females, who seemed the more aggressive, the dominant female was constantly hoarding and marking whilst the submissive female was virtually confined to the square nest box.

(1) The handler for hamsters (see Plate 7) is frequently used in this department in order to introduce an animal to a test situation without direct manual handling. The two concentric plastic beakers (height 14cm, diameter 10cm) may be moved within each other, using the metal bolt, in order that their openings are either aligned, to allow the animal to emerge, or non-aligned, to provide a safe portable container for the hamster onto which a lid may be attached if required. The nut may be used to lock the beakers in position.

Plate 7: Hamster handler (designed by Dr. M. M. Lawlor, Bedford College).

Surprisingly, the dominant female appeared smaller and to have fainter patches on the chest (see Payne and Swanson, 1972). (1) During the course of the experiment they gradually settled more and were occasionally found sleeping together. In the females, then, dominance appeared to be maintained by aggression and intimidation on the part of the dominant animal whilst in the males less overt behaviour was apparent - rather that the submissive male was careful to display submissive behaviour.

All animals manipulated the wooden and cardboard objects. These were moved, chewed and often hoarded with the food stores. In general, it seemed the males hoarded less often than the females, and although both sexes made similar nests those of the males were usually more orderly.

BODY WEIGHT

Analysis of these data shows a highly significant change in body weight, over trials, due to condition. The trials also give a significant result due to the fact that growth occurred over time in these mature animals (see Table 11a). The effect of condition is due to the great increase in weight of both males and females as a result of being placed in an enriched environment for 21 days ($U = 28; 9,4; p < 0.01$).

The females are more affected than the males but this sexual difference does not give any significant interactions on analysis. One would have expected the animals initial weights to have approximated each other due to the similar past histories - by chance, however, the experimental females weighed more than the experimental males whilst, unusually, the control males weighed more than the control females. This difference is exaggerated by the experimental procedure but does not appear significantly in the analysis to either given significant interactions nor to over-ride the main effect (see figure 4).

(1) This may be due to the fact that these animals were caged and observed as littermates who would naturally respond differently to each other than strange animals.

Figure 4. Growth curves of animals over experimental period.

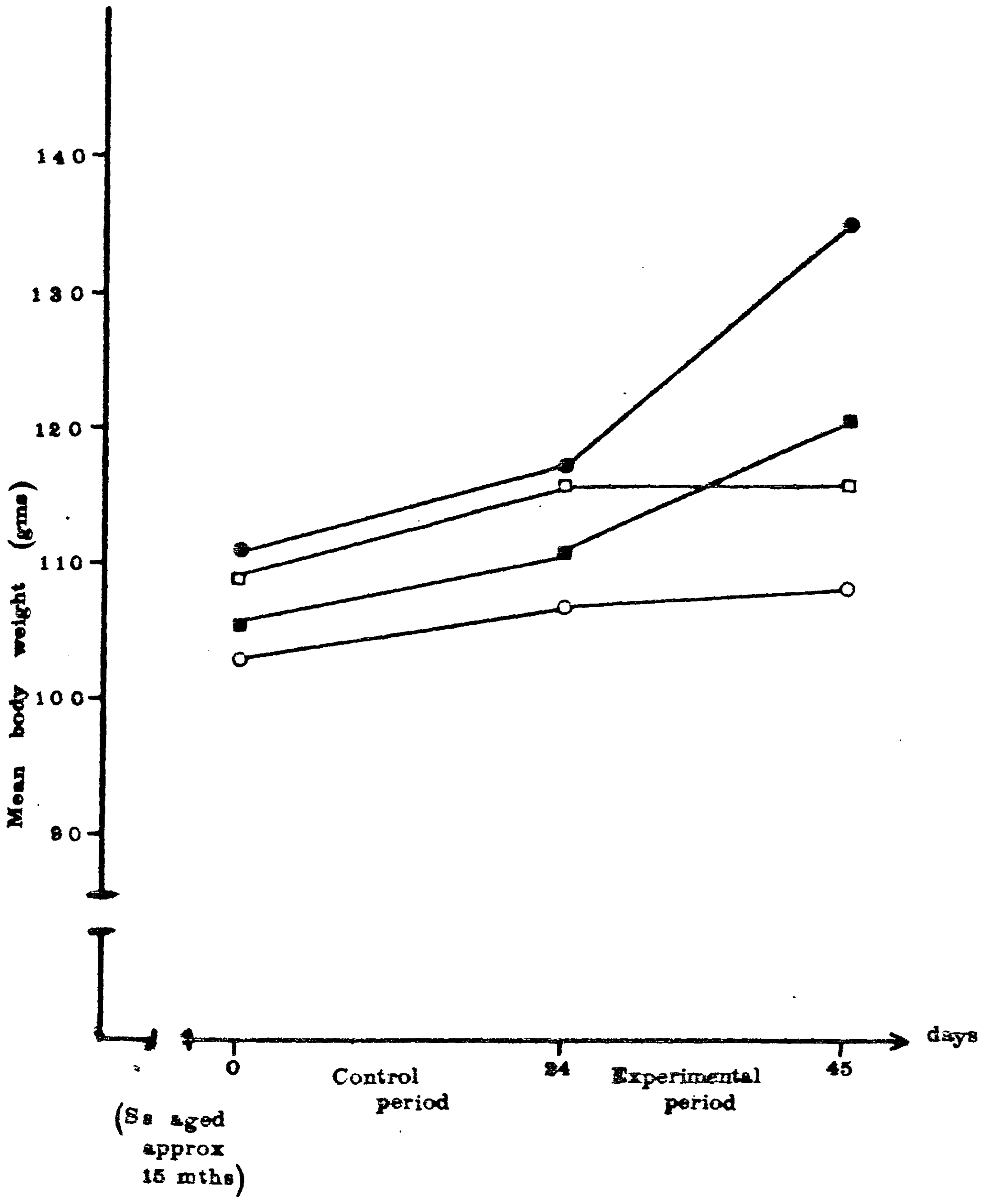


Figure 4

KEY: □ Control males

■ Experimental males

○ Control females

● Experimental females

Table 11a: Repeated measures analysis of variance for body weight.

Source	SS	of	mS	F	P
Conditions	389.82	1	389.82	1.46	n.s.
Sex	5.26	1	5.26	< 1	
C x S	506.15	1	506.15	1.89	n.s.
Error	1894.73	7	267.82		
Total Subjects	2825.88	10			
Weighings	893.52	2	446.76	51.95	$\ll 0.001$
W x C	296.44	2	148.22	17.23	$\ll 0.001$
W x S	38.38	2	19.19	2.23	n.s.
W x C x S	38.38	2	19.19	2.23	n.s.
Error	120.41	14	8.6		
Total	4005.18	32			

Table 11b: Analysis for latency to emerge from the handler in the open-field.

Source	SS	of	mS	F	P
Conditions	6.96	1	6.96	<1	
Sex	0.91	1	0.91	<1	
C x S	3.44	1	3.44	<1	
Error	135.08	7	19.3		
Total Subjects	146.09	10			
Trials	3.43	1	3.43	<1	
T x C	10.24	1	10.24	1.7	n.s.
T x S	8.86	1	8.86	1.47	n.s.
T x C x S	98.63	1	98.63	16.38	<0.01
Error	42.12	7	6.02		
Total	214.59	21			

OPEN-FIELD OBSERVATIONS

No difference in secondary open-field behaviours (such as urination, defecation and washing) were observed between the two groups. Subjectively, the manner of those animals that had experienced the enriched environment was very 'free' in the test situation on the post-experimental trial compared with that of the control animals.

i) Open-field emergence

Analysis of these results only gives a significant higher order interaction of trials x condition x sex (table 11b). A graphical display (figure 5) shows that males normally have slower emergence than females on the first trial, with faster emergence on the second. The enriched environment quickens emergency in both sexes - so exaggerating the normal male response to retesting and totally altering that of the female.

ii) Open-field ambulation

Significant effects are found here due to the interactions condition x sex and condition x trial (see table 11c). The latter effect is explained by the control animals decreasing their level of ambulation on the post-experimental trial whilst the enriched animals (in particular the males) increased theirs (U = 2; 7,4; p 0.01). Scores for total ambulation (that is, inner and outer sections) were used for these analyses as the experimental effect was shown in activity levels in the outer sections, where most open-field ambulation occurs, and this is well reflected in the total scores (see figures 6a,b and c).

Figure 5. Latency to emerge from handler in open-field.

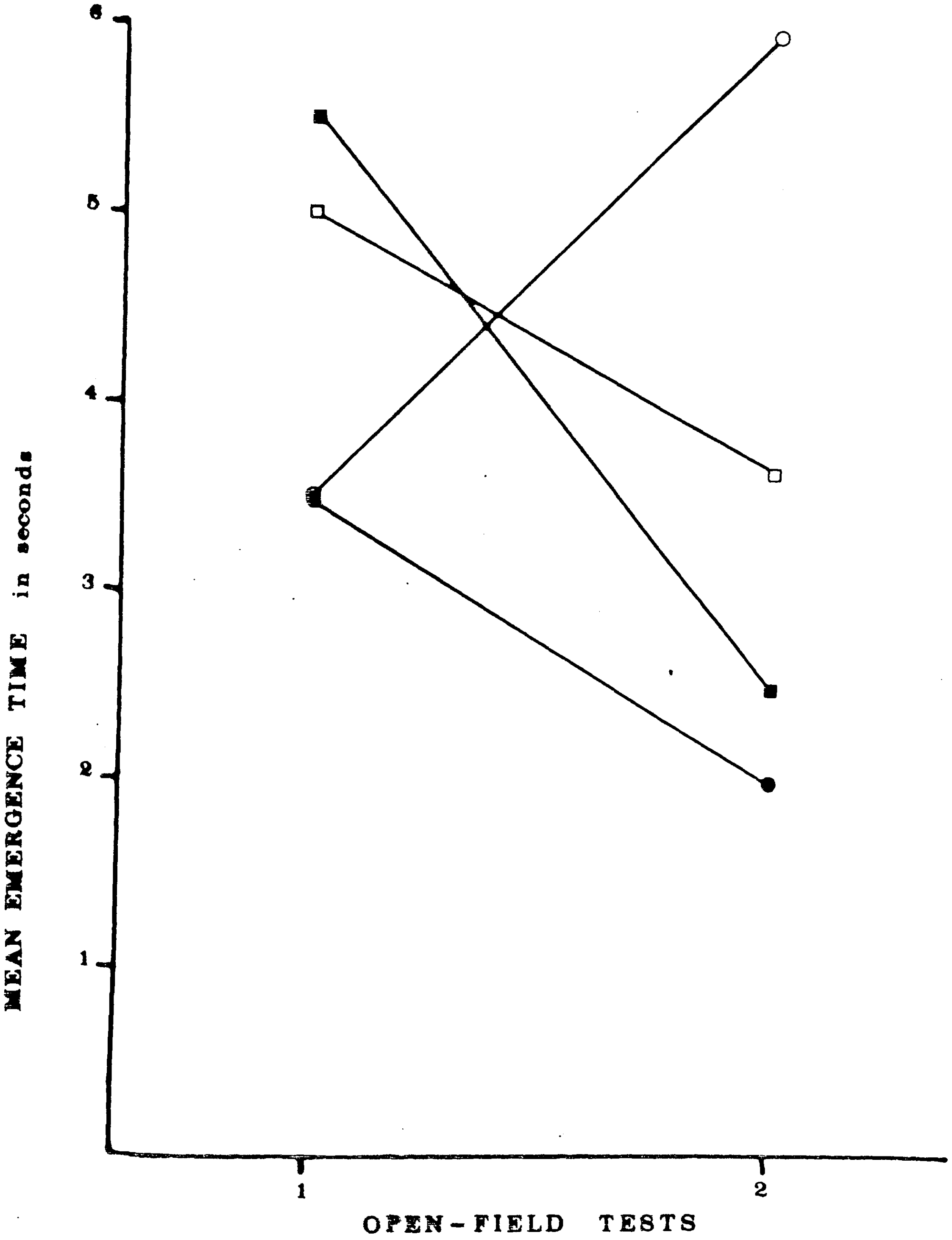


Figure 5

KEY: □ Control males
■ Experimental males
○ Control females
● Experimental females

Figure 6a: Open-field ambulation: total number of inner sections entered

Figure 6b: Open-field ambulation: total number of outer sections entered

Figure 6c: Open-field ambulation: total number of sections entered

KEY:
- ☐ Control males
- ■ Experimental males
- ○ Control fdmales
- ● Experimental females

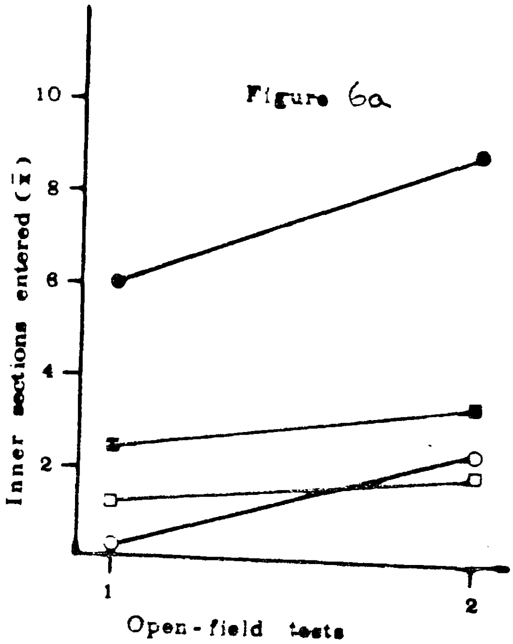


Figure 6a

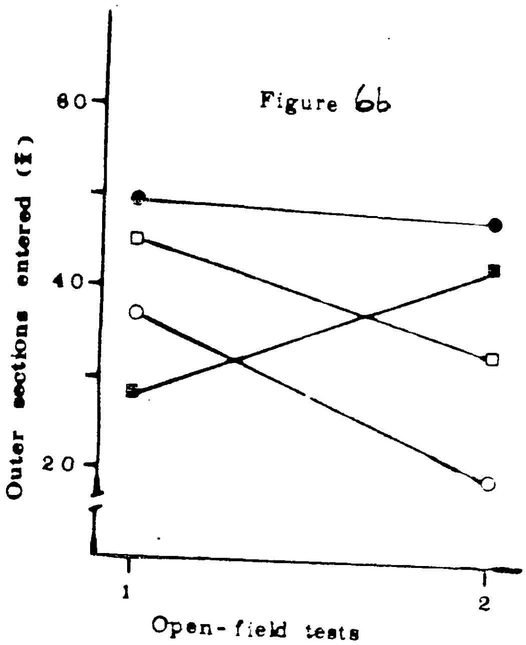


Figure 6b

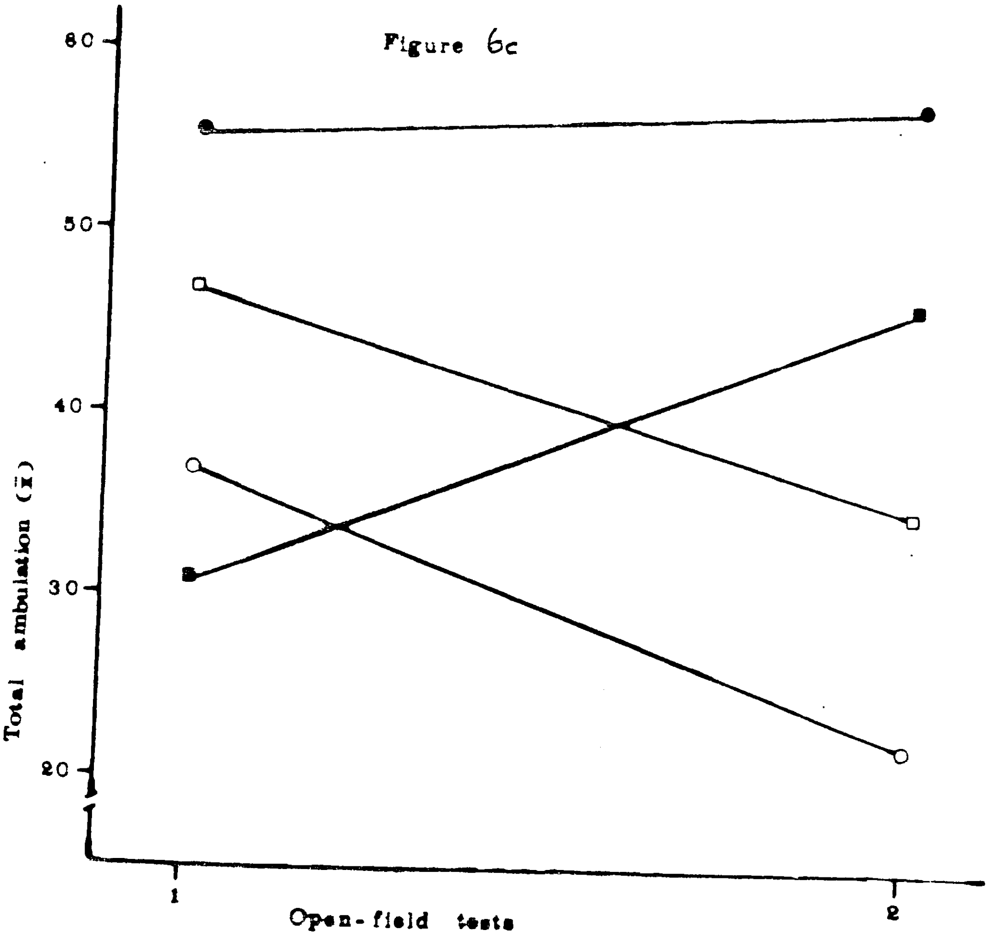


Figure 6c

Table 11c: Analysis of variance for ambulation (total number of sections entered) in the open-field during a 2 minute trial.

Source	SS	of	mS	F	P
Conditions	819.30	1	819.30	2.96	n.s.
Sex	53.22	1	53.22	<1	-
C x S	1096.52	1	1096.52	3.96	<0.1
Error	1939.75	7	277.11		
Total Subjects	3871.27	10			
Trials	25.50	1	25.50	<1	
T x C	637.89	1	637.89	6.32	<0.05
T x S	91.04	1	91.04	<1	
T x C x S	38.10	1	38.10	<1	
Error	706.59	7	100.94		
Total	5464.77	21			

Table 11d: Analysis of variance for rearing occurring in the open-field during a 2 minute trial.

Source	SS	of	mS	F	P
Conditions	81.45	1	81.45	8.18	<0.025
Sex	17.34	1	17.34	1.74	n.s.
C x S	0.115	1	0.115	<1	
Error	69.71	7	9.96		
Total Subjects	175.09	10			
Trials	3.69	1	3.69	<1	
T x C	66.98	1	66.98	6.54	<0.05
T x S	1.17	1	1.17	<1	
T x C x S	20.52	1	20.52	2.01	n.s.
Error	71.71	7	10.24		
Total	331.09	21			

iii) Open-field rearing

The main effect here is one of condition due to the increased rearing shown on retesting in the experimental group, whilst the amount of rearing decreases on retesting in the control group (see table 11d). This response is exaggerated greatly in the males (see figure 7).

In both of the last two analyses, the unexpected segregation of the males and females in the experimental and control groups, as with the weight gains, explains why more interactive effects have failed to reach significance - as may have been expected from the more pronounced effects of testing and experimental condition in the males, as illustrated graphically.

Overall then, the results obtained from the open-field test demonstrating faster emergence, increased ambulation and increased rearing as a result of enrichment fit the subjective impression of animals less emotional and more exploratory as a result of their experience. These alterations in behaviour are more apparent in the male animal than in the female.

Discussion

These results clearly demonstrate that even in a mature laboratory animal a relatively short period of enrichment can dramatically alter that animal's behaviour and physique. That is, enrichment in the hamster produces quicker emergence, increased open-field ambulation and rearing together with increased weight and a fuller expression of social behaviour and organisation. It was unfortunate that the groups as selected should have expressed their sexual dimorphism as they did, as the opposite effect of sex in the two groups has probably affected the analysis. Although it is generally accepted that the female in this species is heavier and more active than the male (Swanson, 1966) this finding is in fact dependent on strain (Lawlor, pers. comm.) and time of testing.

It has been argued that hamsters given the opportunity to exercise lose their ability to regulate their weight (Borer, 1974). This fact, together with the greater availability of food and the demonstrated, and observed, increase in activity, may explain the physical effects on the animal.

Figure 7. Total amount of rearing occurring in the open-field.

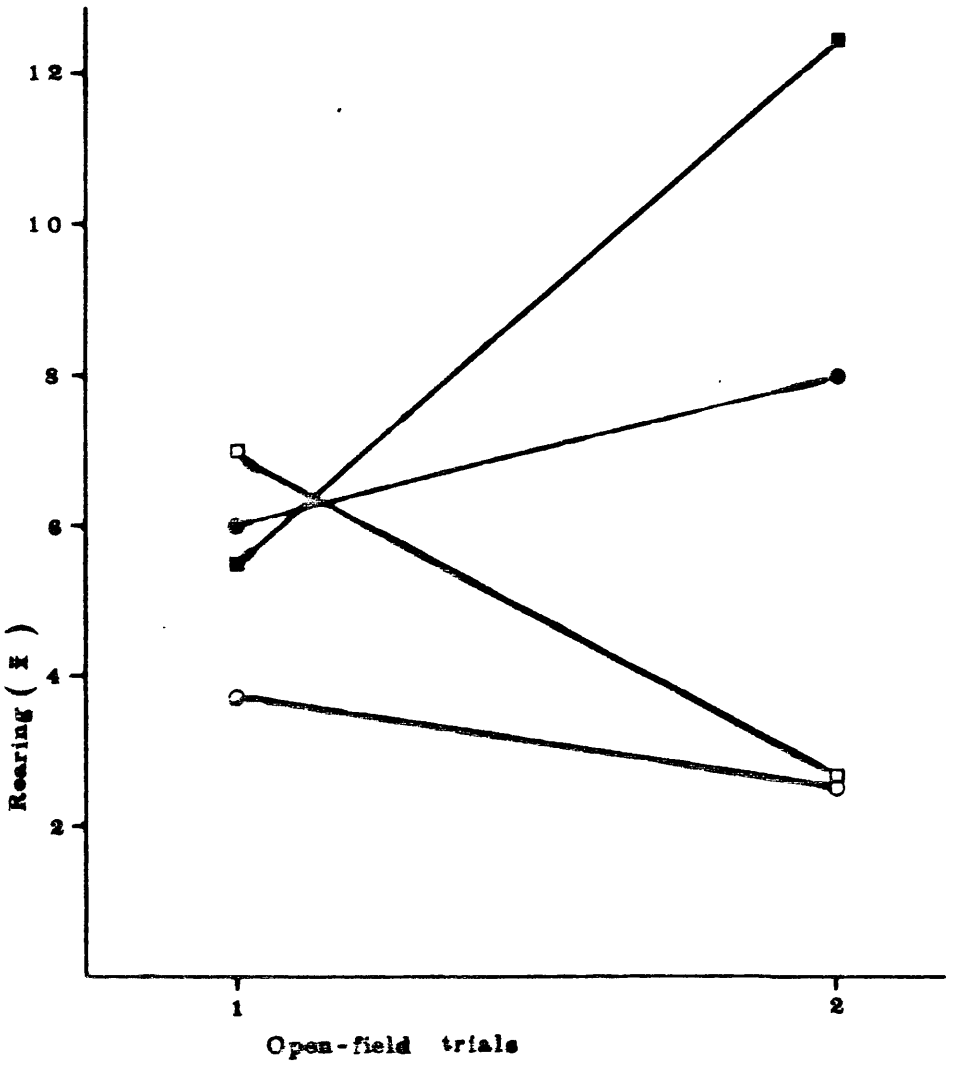


Figure 7

KEY: ◻ Control males
■ Experimental males
○ Control females
● Experimental females

No attempt was made to determine the amount of food actually eaten by these animals, although increases in hoarding behaviour were apparent. A relation between hoarding, housing condition and experience has already been demonstrated in this species (Bevan and Grodsky, 1958). The typical finding in the laboratory rat is that an 'impoverished' rat will show greater weight gain than an 'enriched' rat; and this has been attributed solely to an increased food and water consumption rather than any metabolic alteration (Fiala, Snow and Greenough, 1977). One explanation for such a result may be the generally depressed level of activity in the isolates as Mayer (1968) has demonstrated that an organism must reach some minimal level of activity before it begins to regulate its intake in accord with its needs. The food intake in rats with very low levels of activity is greater than in rats showing moderate levels of activity. This seems, therefore, to be yet another paradoxical result from the hamster (see Marques and Valenstein, 1976 and Gregory, 1975) in that enrichment leads to both the increased weight gain and the increased activity. Such a difference in the physiological effect of enrichment may simply be a reflection of the differing physiology and lifestyle of these two species.

Generally, it may be stated that those animals from the enriched environment were less emotional and more exploratory than the control animals. The fact that exploration increased seems as intuitive expectation of enrichment in a species where novelty has been shown to be rewarding (Sykes, 1962). Increased exploration and higher levels of activity are found in rats exposed to similarly enriched environments (Inglis, 1975). That these rats also commonly show improved learning ability indicates that the hamsters in this study would also probably have done so, as a general relationship across species has been established between high levels of exploration and good learning performance (Lester, 1974).

The fact that these alterations in behaviour were produced in mature animals confirms the findings of Inglis (1975) with rats of a similar age, thereby repudiating the suggestion that enrichment operates via maturational changes in producing it's effects as proposed by earlier workers in the field of early stimulation (e.g. McReynolds, 1962). Such misinterpretation has arisen due to the tendency to study the influence of prolonged sensory experience solely in weanling or immediately post-weaning animals. Although certain types of early sensory environment may profoundly alter certain physiological processes, such as sensory processing in the brain following sensory restriction (Edward, Barry and Wyspianski, 1968; cited by Inglis, 1975), it is now becoming apparent that the adult animal is equally capable of adaptive change as a result of it's environment as a juvenile (see Rosenzweig, 1966).

In conclusion, then, it may be stated that the mature golden hamster responds to a period of environmental enrichment in a similar manner behaviourally as a mature rat, although the physiological response to the experience, as reflected in body weight, is dissimilar. Such a finding demonstrates the plasticity of an organism irrespective of it's maturational stage.

SECTION 2: TESTING THE EXPERIMENTAL HYPOTHESIS

SECTION 2; TESTING THE EXPERIMENTAL HYPOTHESIS

The experiments reported in this section were an attempt to test the experimental hypothesis, originally suggested by Daly (1973) and discussed fully in Chapter II, that the laboratory is an overstimulating environment for infant rodents and an understimulating one once the young reach weaning age. The main hypothesis concerned the comparison of "normal" laboratory rearing conditions pre- and post-weaning with experimental rearing conditions designed to approximate more closely to those the animal might encounter in its natural habitat. The concept should therefore apply to all rodent species that naturally raise their young in a burrow, although whether they are solitary or colonial may be an additional variable. Such a conceptualisation of the study of early experience is more appropriate than the usually accepted misinterpretation of the consequences of stimulating the young organism as augmenting a deficient environment. Experimental hypotheses were set up as follows, under three separate subheadings, to allow both aspects of the hypothesis to be tested as well as the overall interactive effect. Formulated in this way it should be possible to separate the contribution of the various components of the early environment towards the adult organism's apparent emotionality, physiology and behaviour. This section, however, cannot be as precise in the predictions made as the rat, because a broad concept is under investigation rather than a specific experimental hypothesis derived from known experimental effects. Much of the background information and standard data that might be useful is simply not available largely because the golden hamster is the experimental animal and our knowledge of it is as yet rather imperfect.

(i) The preweaning conditions

These comprise three separate conditons - (a) simulated burrow, (b) normal laboratory and (c) handling days 0-21. This should allow for a stimulation continuum with handling in infancy providing stimulation in excess of that normally encountered in the laboratory, and therefore may be used as a contrast condition for the low-level stimulation pseudo-burrow.

It was predicted that animals reared in the burrow would show least signs of stress (i.e. would have better growth, smaller adrenals, and lower resting plasma cortisol levels) when adult than those animals reared in the laboratory or those in the handled group. The behavioural measures would reflect this phsyiology in that the burrow reared animals should be less emotional (in the open-field), less neophobic and may learn more rapidly.

(ii) The postweaning conditions

These comprise two separate conditions - (a) normal laboratory and (b) semi-natural free-enriched environment. This environment has been shown by the pilot study to provide a degree of enrichment sufficient to result in changes in physiology and behaviour, and is therefore appropriate for the purposes of this test. Predictions were made that those animals experiencing enrichment would be more active in the open-field, less neophobic and learn more readily. Physiologically they would have greater body growth and larger brains than those animals reared in the laboratory condition.

(iii) To test the overall hypothesis

In this section it was necessary to look at the effect of both the lower stimulation in infancy and the greater stimulation postweaning in combination, compared with animals reared in "normal" laboratory conditions. The hypothesis predicts that those animals experiencing burrow preweaning and enrichment postweaning will show an effect on all measures which follows Daly's prediction as it has been formulated here.

SECTION 2(i); PREWEANING CONDITIONS

The three experimental conditions relevant to this section are the burrow (0-3 weeks) to lab (3-6 weeks) (B-L); the handled daily (days 0-21) (H_{0-21}) and the control group (L-L).

Behavioural observations were made during routine inspections of the litters (3/conditon) and these are detailed in Appendix A. It may briefly be stated that differential maternal behaviour is thought to occur in these conditions and that those females in the burrow condition give best care to their young whilst those in the handled condition do worst.

The average size of the litters in these three conditions was burrows6.8, lab 8.8 and handled 9.7; and two of the handled litters produced pups with mixed coat colour - two factors which may be considered to attribute unanticipated independent variables. There was no dramatic loss of young pups in the handled groups, as had been expected, although over time they do not live so long. Those reared in the burrow seem, in general, to live particularly long within the range for laboratory hamsters.

Table 12a: Repeated measures analysis of male body weight in preweaning conditions (litter means)(3 litters/condition).

Source	SS	d.f.	mS	F	p
Conditions	1,248.17	2	624.09	3.36	n.s.
error	1,114.33	6	185.72		
Total subjects	2,362.50	8			
Tests	22,049.44	3	7,349.81	319.84	<0.001
T x C	159.39	6	26.57	1.16	n.s.
error	413.67	18	22.98		
Total	24,985.00	35			

Table 12b: Repeated measures analysis of female body weight in preweaning conditions (litter means)(3 litters/condition).

Source	SS	d.f.	mS	F	p
Conditions	1,066.89	2	533.45	1.24	n.s.
error	2,583.00	6	430.50		
Total subjects	3,649.89	8			
Tests	26,517.89	3	8,839.3	149.77	<0.001
T x C	181.78	6	30.30	<1	
error	1,062.33	18	59.02		
Total	31,411.89	35			

Table 13a: Body weights of males and females at 6 weeks (litter means)

Source	SS	d.f.	mS	F	p.
Conditions	320.11	2	160.06	1.83	n.s.
Sex	34.72	1	34.72	<1	
C x S	8.78	2	4.39	<1	
Error	1,048.0	12	87.33		
Total	1,411.61	17			

Table 13b: Body weights of males and females at 12 weeks (litter means)

Source	SS	d.f.	mS	F	p.
Conditions	941.77	2	470.89	2.58	n.s.
Sex	288.0	1	288.0	1.58	n.s.
C x S	5.34	2	2.67	<1	
Error	2,191.33	12	182.61		
Total	3,426.44	17			

Table 13c: Body weights of mature males and females used in Physiological sample (individual scores), (N = 40).

Source	SS	d.f.	mS	F	p.
Conditions	3,466.42	2	1,733.21	14.09	<0.001
Sex	1,985.93	1	1,985.93	16.15	<0.001
C x S	638.31	2	319.16	2.6	=0.1
Error	4,180.98	34	122.97		
Total	10,463.10	39			

Growth

It is appropriate to consider the general health and growth of the animals in these conditions. Although the only significant result on analysis was between the weights of mature animals (90+ days) in the physiological sample (tables 12 and 13), the growth curves of the three conditions are quite distinct (see figure 8). They show that the handled animals grew least, the burrow-reared animals had improved growth and that the control animals had the highest growth rate. There is no significant difference in growth due to sex, nor any differential effect from the experimental conditions due to this variable.

The fact that the results for younger animals were insignificant whilst those for the mature animals were highly significant (see table 13) tempts one to emphasise the importance of an animals' experiential history between exposure to the experimental condition and the testing procedure in determining the ultimate effect of the early experience (see Essman, 1971). However, in this case, the actual time between the final weighings of the "younger" animals (12 weeks i.e. 84 days) and the commencement of sampling 'mature' animals for physiological survey (90+ days) denies this argument. Instead, one must be wary of interpreting sample data as true for an entire population. The analysis result must largely be due to the individual weights of the mature females from the B-L condition being much greater (125 gms on average) than the average litter means used as scores in the other analyses, whilst other values remain similar (see table 14).

Table 14: Comparison of individual and population values obtained for body weight

Experimental Condition (days 0-21)	Sex	Mean litter weight ($\bar{x}$) (84 days)	Individual weight ($\bar{x}$) (90+ days)
Burrow - lab	Male	101 gms.	100 gms.
	Female	110 gms.	125 gms.
Lab - lab (control)	Male	109 gms.	107 gms.
	Female	117 gms.	117 gms.
Handled	Male	92 gms.	88 gms.
	Female	99 gms.	96 gms.

Figure 8. Growth curves of litters reared in neonatal conditions:

(a) males (N = 39).

(b) females (N = 37).

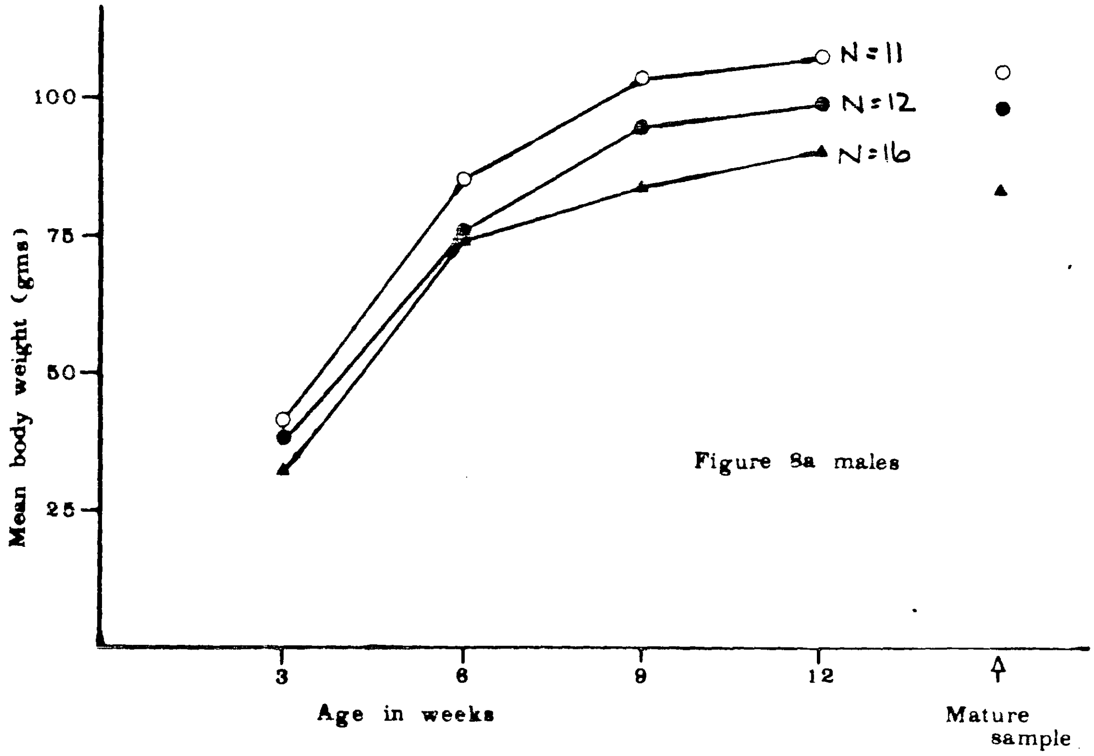


Figure 8a males

● B-L ○ L-L ▲ H_{0-21}

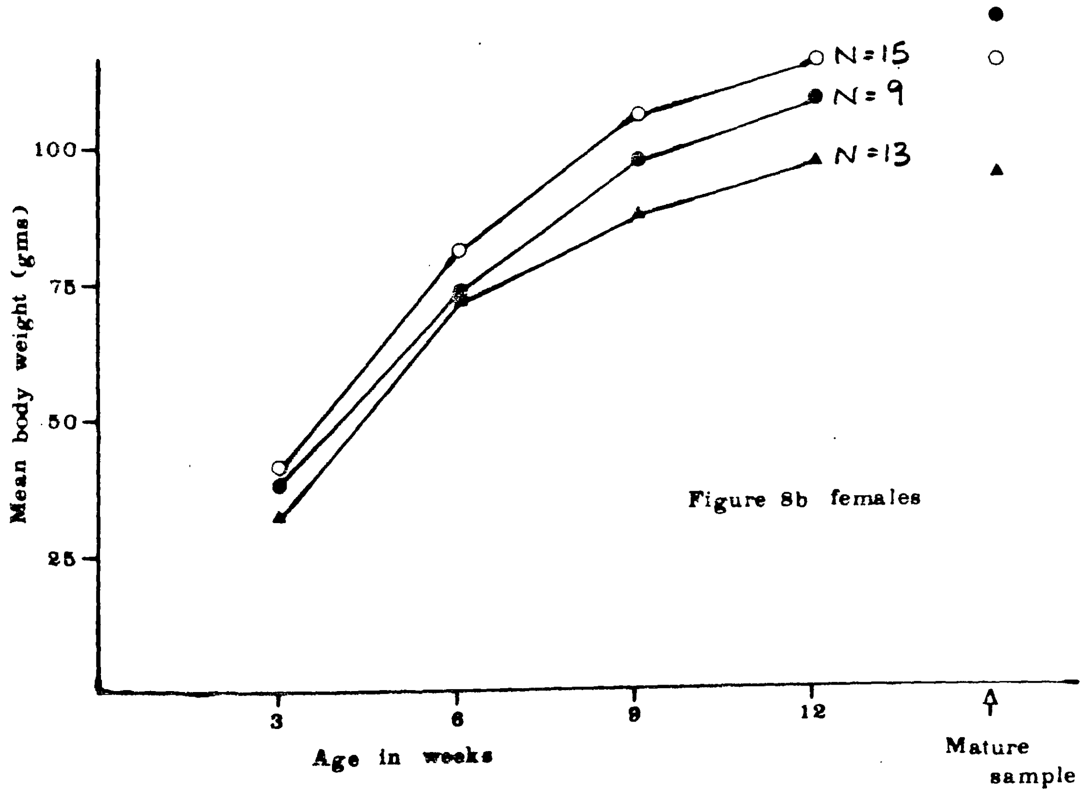


Figure 8b females

Open-field behaviour

All animals from 3 litters in each condition were tested and the results analysed using litter means. Standard open-field techniques were used, scoring ambulation and rearing as described on p.125.

In general, the females were more active in the field (as would be expected, see Swanson 1966); the control animals were more active than those reared in the burrow, at least on day 1 of testing; and the handled animals had very low ambulation scores. The handling effect was not apparent in the results for the females, nor was the ambulation of those females reared in the burrow significantly lower than that of the other groups (see figures 9 and 10). The handled males were less active than any other group, both ambulation and rearing in the field being minimal. The handled animals could on these criteria be judged more emotional or nervous than the other groups. No support can be found for a theory that early handling in this species decreases emotionality, insofar as this is measured by open-field scores, as it may do in laboratory rats.

The low ambulation scores of the burrow reared animals on day 1 (compared with lab-reared scores) should be interpreted in the light of the flat shape of the graph; the behaviour varied little over the 4 days in novel surroundings. The rearing scores are not high in either the males or the females in this condition. These results are possibly best understood as a response to the open-field which is characterised neither by excitement which habituates over days of testing nor in activity characteristic of fear. There is no evidence from the literature (Schiffman, 1971) that low light leads to deterioration of the visual system in nocturnal rodents and observation of these animals and their behaviour in the open-field would not lead one to question this finding. A nocturnal animal like the hamster should be as well-adapted to minimal light levels in the neonatal period as the laboratory rat. The burrow reared animal's response to the open-field is therefore unlikely to be attributable to any abnormality of their visual system but rather is a matter of emotional adaptation.

Figure 9. Open-field ambulation of litters reared in neonatal conditions:
total sections entered (a) males (N = 39).
(b) females (N = 37).

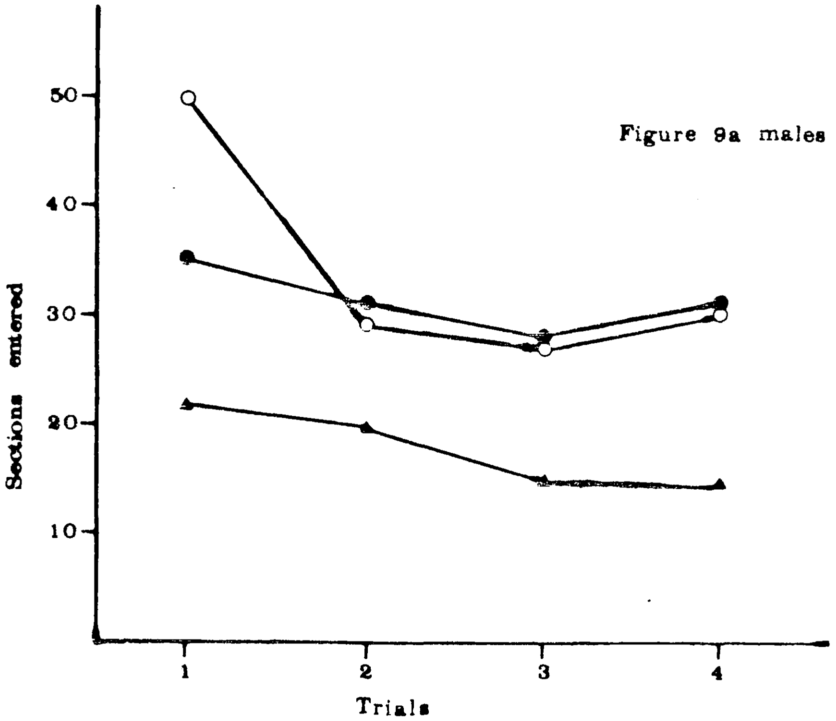


Figure 9a males

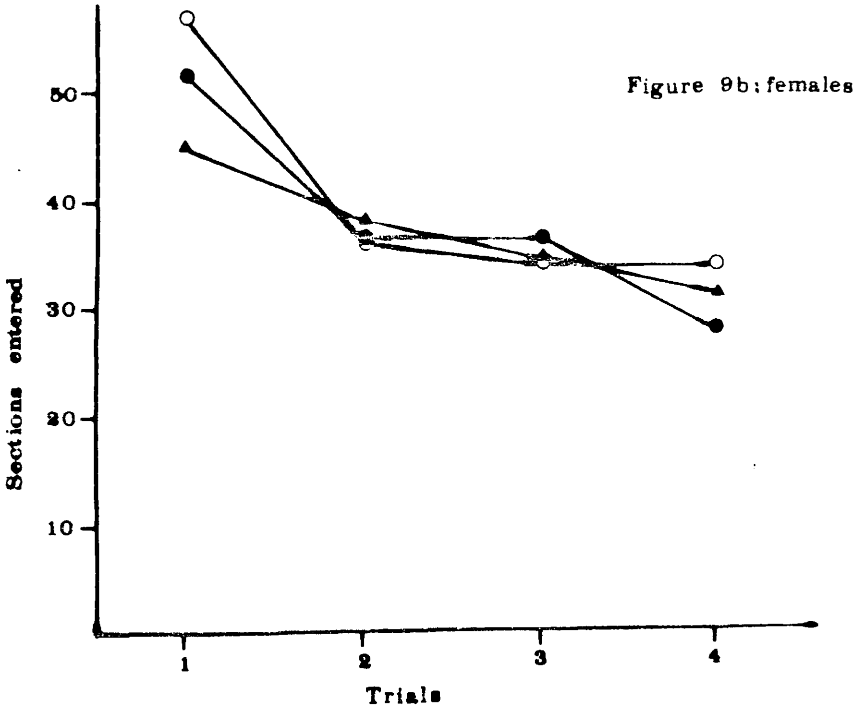


Figure 9b; females

● B-L ○ L-L ▲ H_{0-21}

Figure 10. Open-field rearing of litters reared in neonatal conditions:

(a) males (N = 39).

(b) females (N = 37).

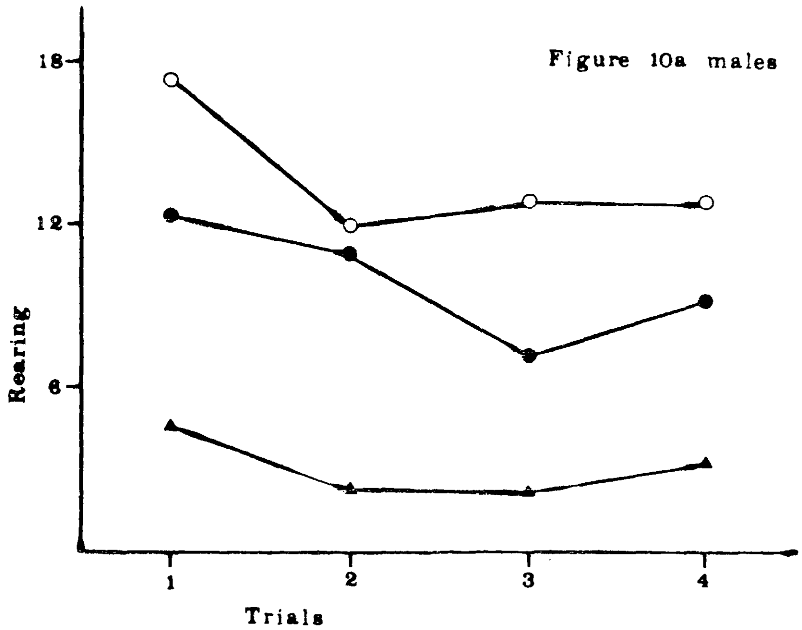


Figure 10a males

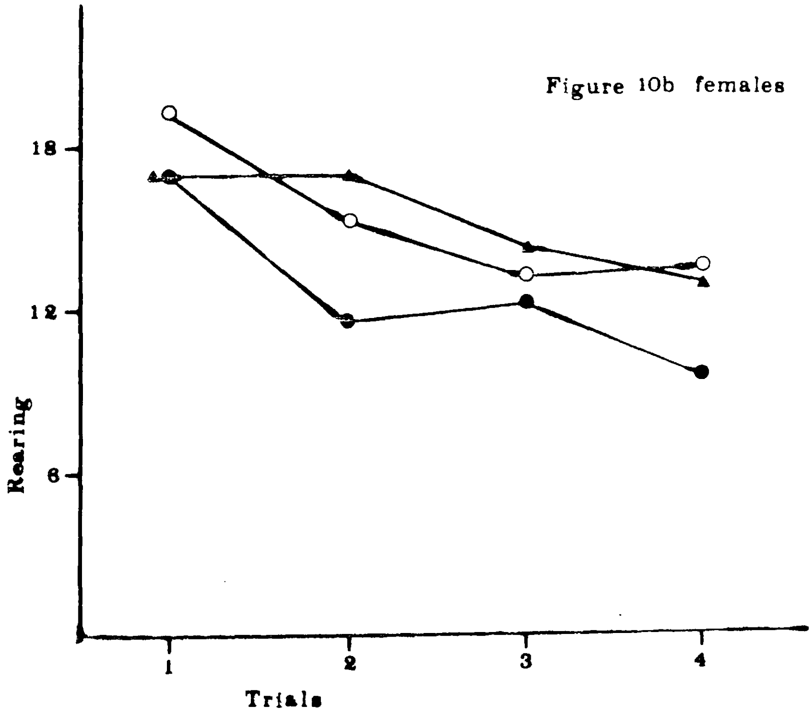


Figure 10b females

● B-L ○ L-L ▲ H_{0-21}

The female results show little effect from any condition and this could have been expected as they are usually less susceptible to both physiological and behavioural manipulation than the males, although there are no significant S x C interactions. There is a significant sex difference in open-field ambulation and rearing due to the greater activity of the females (see tables 15a and 15b). The significant interactions of T x C and T x S in the analysis for ambulation must largely be explained by the greater effect of condition on the males' and the differential response of the two sexes to the testing procedure.

Table 15a: Open-field ambulation in males and females (with different early environments) over a 4-day trial (3 litters/condition).

Source	SS	d.f.	mS	F.	p.
Within subjects					
Condition	1213.36	2	606.68	2.3	n.s
Sex	2156.05	1	2156.05	8.17	<0.025
S x C	697.86	2	348.93	1.32	n.s
error	3165.17	12	263.76		
Total subjects	7232.44	17			
Between subjects					
Trials	2560.5	3	853.5	24.05	≪ 0.001
T x S	247.83	3	82.61	2.33	<0.1
T x C	512.41	6	85.4	2.41	<0.1
T x S x C	119.26	6	19.88	<1	
error	1277.5	36	35.49		
Total variance	11949.94	71			

Table 15b: Open-field rearing in males and females (with different early environments) over a 4-day trial (3 litters/condition).

Source	SS	d.f.	mS	F.	p.
Within subjects					
Condition	352.53	2	176.27	1.08	n.s.
Sex	539.02	1	539.02	3.31	<0.1
S x C	406.86	2	203.43	1.25	n.s
error	1952.33	12	162.69		
Total subjects	3250.74	17			
Between subjects					
Trials	214.82	3	71.61	9.61	<0.001
T x S	22.82	3	7.61	1.02	n.s
T x C	24.47	6	4.08	<1	
T x S x C	32.8	6	5.47	<1	
error	268.34	36	7.45		
Total Variance	3813.99	71			

Novelty Testing

All animals from the three litters in each condition were tested, using the procedure described on p.126, and scoring for latency of response and total time on object. The first measure, that of latency of response to the objects, gives significant results by trial for both sexes and a significant trials by condition interaction in the males (see table 16). The second measurement, that of time on objects, however, gives no significant results at all. It was decided that the results for this measure were so variable in this species as to make it virtually useless for interpretation. The results obtained, however, when displayed graphically, (figure 11), are fairly consistent, in that: females spend more time on the objects than males; both sexes spend less time on the second than the first object; the experimental conditions serve to eliminate the sex difference by bringing the scores of the females down to the level of the males' scores, and to greatly depress the amount of time spent on the first object - handling depresses exploration of the objects more so than the early burrow condition.

The analysis result for latency of response is explained by reference to the graph of the results (see figure 12) - all latency times to the second object increase except in the case of the handled males. This is surprising as the female results closely follow those of the control group, again demonstrating the same female indifference to experimental manipulation as shown by the open-field behaviour. The explanation seems to be that the handled males are very nervous of the first object when it is introduced resulting in a very long latency time, and simply reacted sooner to the second object as they were more at ease. The control and burrow males respond to the first object and then have a long latency to the second object as they appear to find little of interest in the situation. Both the male and female scores for the burrow condition are shorter than the control group showing that they have quick and efficient responses in a novel situation.

The results from this test were disappointing after the very definite results shown when used as a test to distinguish between rats with different early experience (Wells, 1975). It seems that it is not so suitable for this species as the hamster spends a great deal of time in the corners of the test box digging and seems to pay little attention to the test situation after the first few minutes - to the extent of only noticing the second object when they fell over it.

Table 16a: Analysis of reaction time of males to novel objects (N=39).

Source	SS	d.f.	ms	F	p.
Conditions	517.33	2	258.67	<1	
error	1849.67	6	308.28		
Total subjects	2367.00	8			
Trials	460.06	1	460.06	6.66	<0.05
T x C	1223.11	2	611.56	8.86	<0.025
error	414.33	6	69.06		
Total	4464.50	17			

Table 16b: Analysis of reaction time of females to novel objects (N=37).

Source	SS	d.f.	ms	F	p.
Conditions	124.00	2	62.00	<1	
error	1549.00	6	258.17		
Total subjects	1673.00	8			
Trials	1334.72	1	1334.72	6.84	<0.05
T x C	69.78	2	34.89	<1	
error	1171.00	6	195.17		
Total	4248.50	17			

Figure 11. Total time spent on objects in novelty test by litters reared in neonatal conditions: (a) males (N=39).
(b) females (N=37).

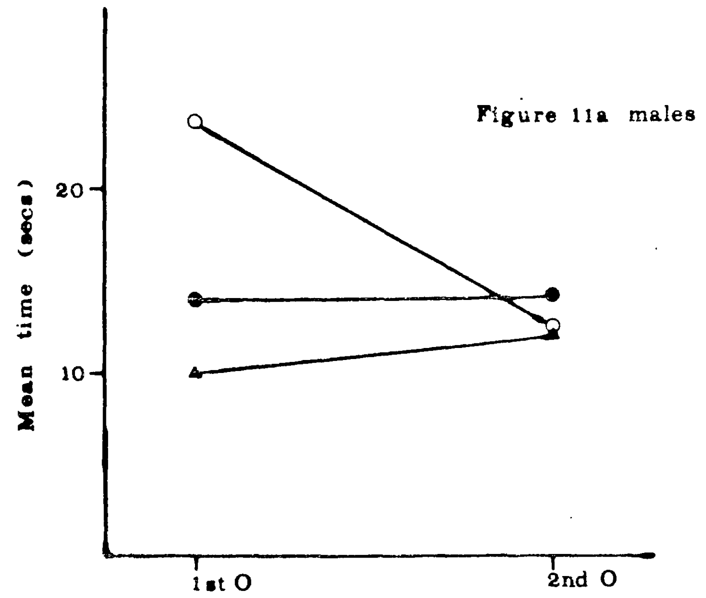


Figure 11a males

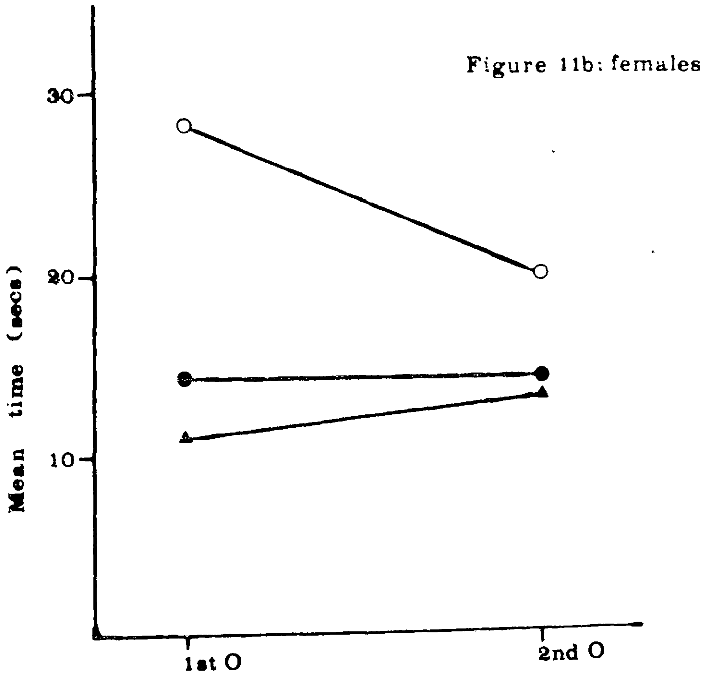
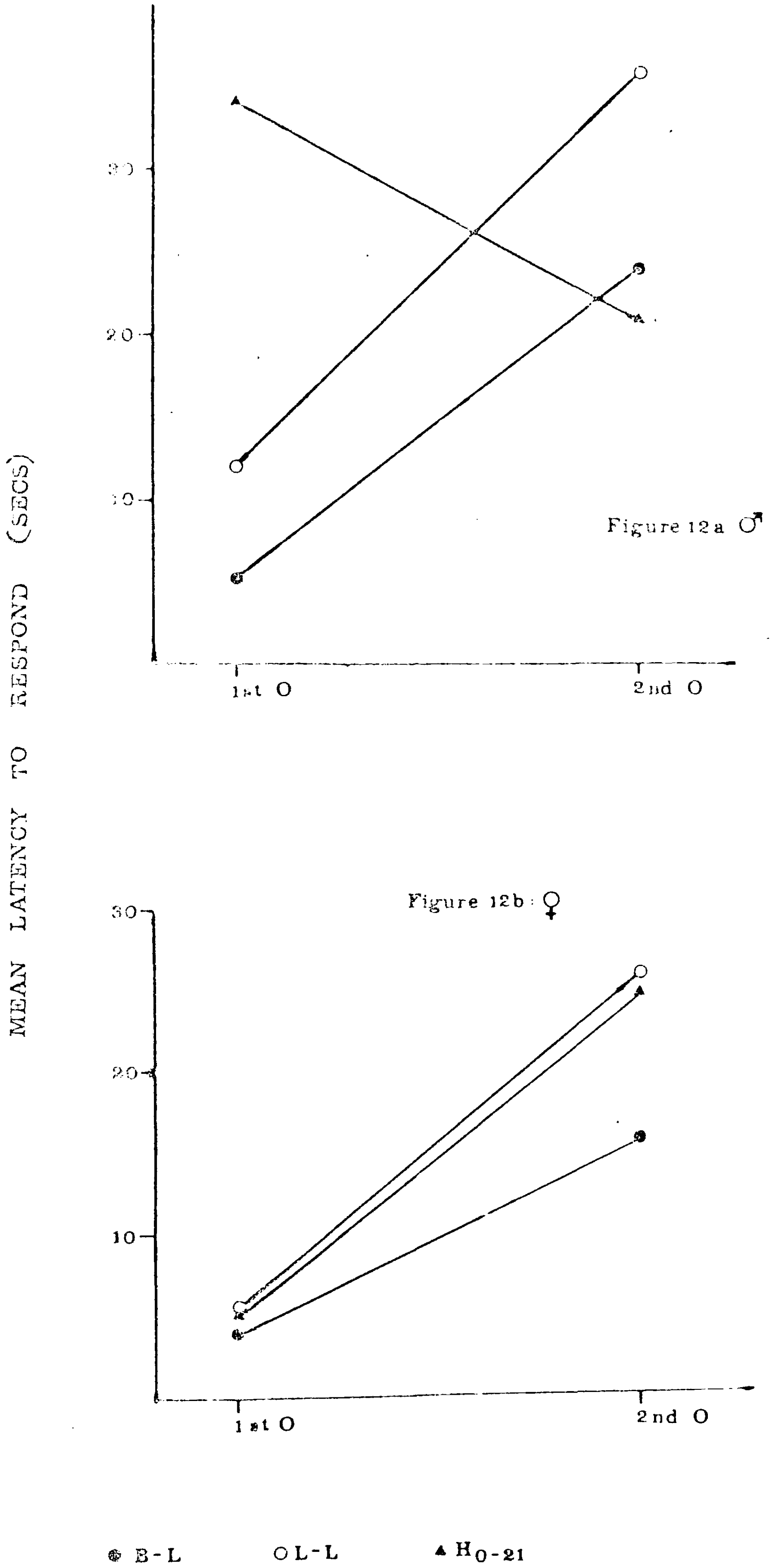


Figure 11b: females

● B-L ○ L-L ▲ H0-21

Figure 12. Latency of response to objects in novelty test of litters reared in neonatal conditions: (a) males (N = 39)

(b) females (N = 37)


MEAN LATENCY TO RESPOND (SECS)
30
20
10
1st O
2nd O
Figure 12a ♂
Figure 12b : ♀
30
20
10
1st O
2nd O
● B-L
○ L-L
▲ H0-21

One interesting result of this test was the differences in ambulation levels, during the first two minutes of testing, between the groups. The sex difference shown in the open-field is very clear with the males ambulating less than the females; and the handling accentuates this difference by depressing the male levels and increasing the female - although the conditions are insignificant in analysis (see table 17 and figure 13).

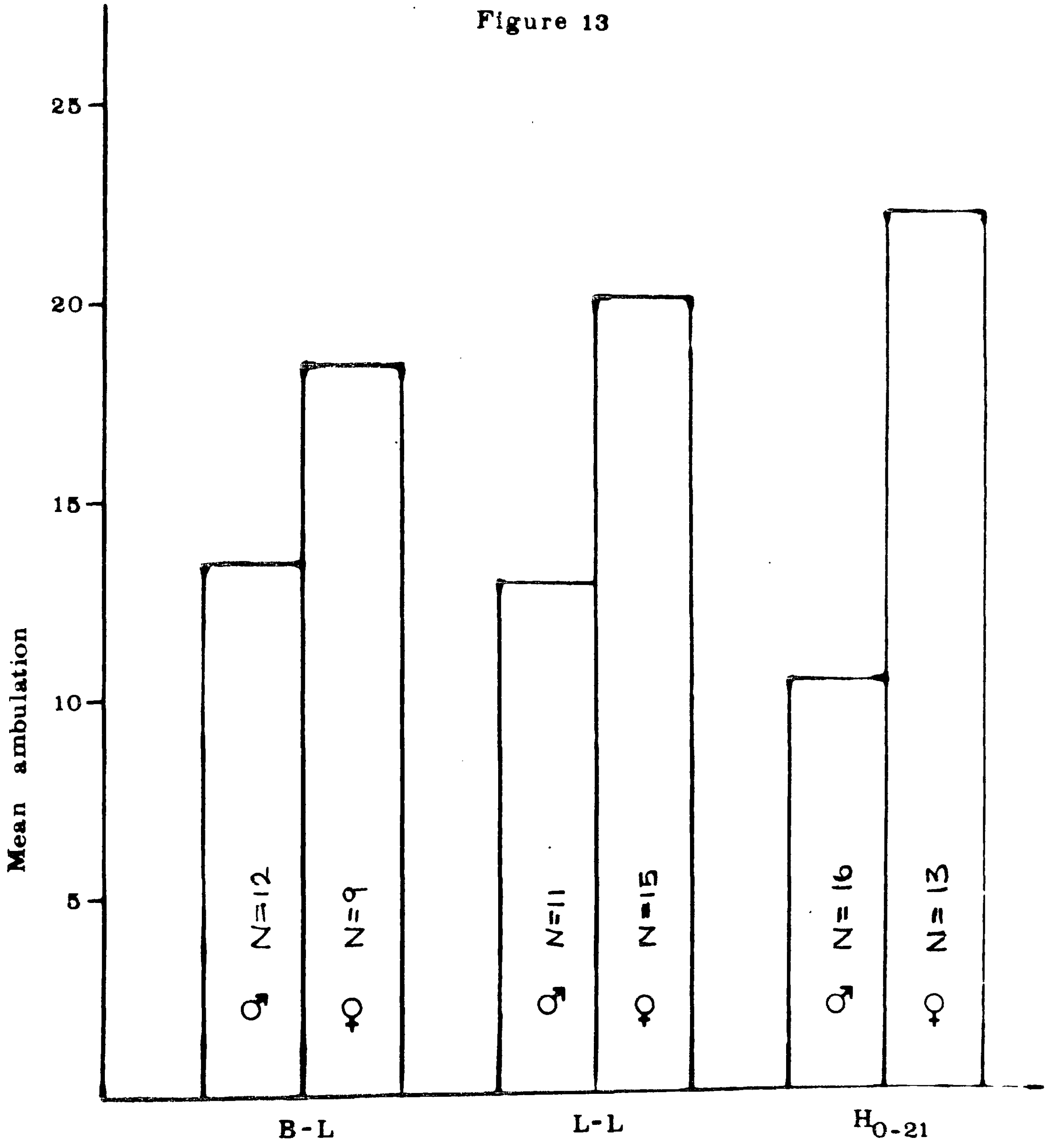
Table 17: Analysis of ambulation in the novelty box during period of adaptation (N = 39♂, 37♀).

Source	SS	d.f.	ms	F	p.
Conditions	1.44	2	0.72	<1	
Sex	288.0	1	288.0	26.99	<0.001
Sex x Conditions	39.0	2	19.5	1.83	n.s
error	128.0	12	10.67		
Total variance	456.44	17			

Figure 13. Novelty test ambulation of litters reared in neonatal conditions: (a) males

(b) females

Figure 13



Discrimination Learning

Looking at the analysis of these results (table 18) they show that all animals learnt the correct discrimination response within the learning trials provided, with no significant differences between the conditions at the 5% level. The value obtained for F is significant at the 10% level which, together with the small sample size, indicates an effect. However, behavioural differences were apparent in the acquisition of this response.

An indication of this different behaviour is given by the times taken within each group to complete the learning trials (table 19). Those animals reared in the burrow show efficient purposeful behaviour with little prevarication resulting in short trial times, they are calm throughout and make good use of the reinforcers available in the goal box. The handled animals also show that they have good learning ability but their extreme nervousness leads to longer trial times and more erratic behaviour, they also make little use of the goal box - seemingly afraid of their own shadow! The control group animals were also quite excited by the procedure but not in such a nervous manner, more in the manner that they were in a novel environment that could be explored, which led to much longer trial times. These three types of behaviour seem reflected in the shape of the learning curves obtained (figure 14).

Table 18: Analysis of number of correct responses made during discrimination learning (3 males only /condition)

Source	SS	d.f.	mS	F.	p.
Conditions	21.55	2	10.78	3.88	<0.1
error	16.67	6	2.78		
Total subjects	38.22	8			
Trials	410.33	3	136.78	51.23	<0.001
T x C	30.67	6	5.11	1.91	n.s
error	48.00	18	2.67		
Total Variance	527.22	35			

Figure 14. Discrimination learning curves of males reared in neonatal conditions: total number of correct responses (N=9)

Figure 14

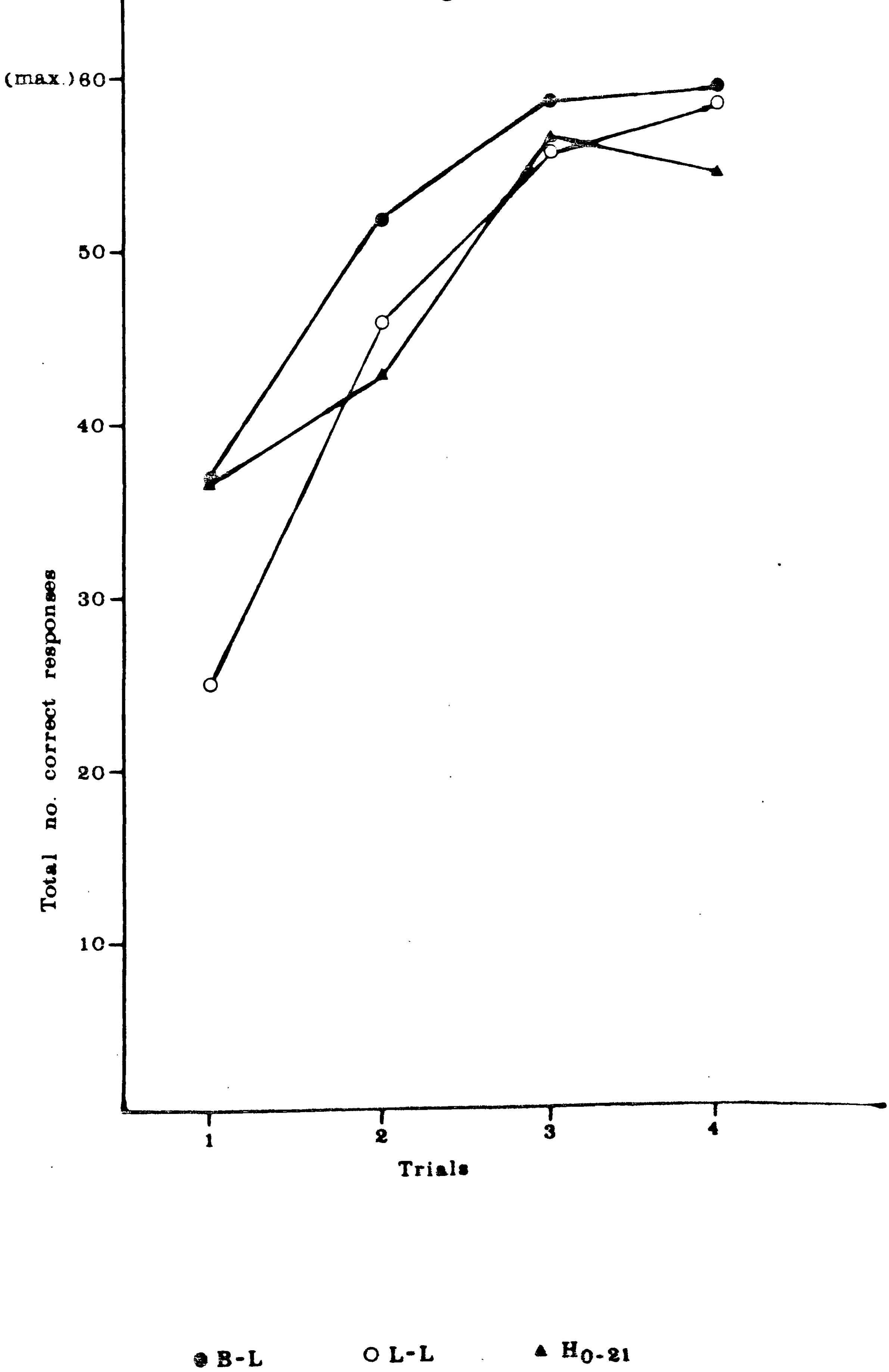

(max.) 60
50
40
30
20
10
Total no. correct responses
1
2
3
4
Trials
● B-L
○ L-L
▲ H0-21

Table 19: Analysis of trial times taken during discrimination learning (males only)

Source	SS	d.f.	mS	F.	p.
Conditions	128.74	2	64.37	10.64	<0.05
error	36.30	6	6.05		
Total subjects	165.04	8			
Trials	74.27	3	24.76	17.31	$\leqslant 0.001$
T x C	34.75	6	5.79	4.05	<0.01
error	25.70	18	1.43		
Total Variance	299.76	35			

From these behavioural tests we may therefore form a picture of the type of animal produced by the manipulation of early environment on a 'stimulation continuum'.

In the control condition, the typical laboratory hamster appears to be an animal with a fairly high exploratory tendency which possibly over-rides a more natural and adaptive reticence in a novel situation. When reared in a more natural and less stimulating environment, even in a first generation, the hamster immediately shows a calmer, efficient nature which maximises the potential of an environment whilst minimising the animal's emotional and physical expenditure. The handling procedure, causing a high level of neonatal stress, produces an animal which, whilst being quite able to react and learn within its environment, is often seemingly in a state of continual nervous tension which must utilise a great deal of energy resulting in depressed maintenance and social behaviours (see Appendix A).

These behavioural changes appear to have been initiated at a very early age. The most likely hypothesis would be that they are mediated by the maternal behaviour directed towards the pups together with the general level of stimulation within the environment bearing directly upon them. As Levine (1969) suggests, this may lead to a 'setting' of both physical and psychological status in the adult animal.

Physiological Data (analysed using harmonic mean)

i) Brain Weight

These data gave a very definite conditions effect (table 20a) showing improved growth in the burrow condition and impaired growth, particularly in the males, in the handled condition. Although the females appear less affected by the handling procedure there is no sex x conditions interaction. The result would seem to indicate that those animals reared in a burrow have a more efficient physiological system resulting in a larger brain compared with the controls - the size of brain is not related simply to body size (see growth curves figure 8 and figure 15a) and is more an index of nutritional status, physiological efficiency and an adaptive responsiveness to the environment. This lack of relation between brain size and body size is demonstrated by the results for the analysis (Table 20b) and the graph (Figure 15b) of brain/body weight ratio.

The relationship between brain growth, general body growth and cognitive ability is not a simple one. On all these measures the three conditions give varying results but not a stable continuum. For example, in the handled animals, both brain weight and body weight are depressed but learning ability (for a simple task) is at least as adequate, if not improved on, as in the control condition. Conversely, the burrow-reared animals show higher brain weight and improved learning ability but lower general body weight.

Table 20a: Analysis of brain weights in males and females with different early experience. (N = 20 F, 19 M).

Source	SS	d.f.	mS	F	p
Conditions	312.46	2	156.23	5.88	< 0.01
Sex	52.65	1	52.65	1.98	n.s.
Sex x Conditions	79.57	2	39.79	1.5	n.s.
Error	876.29	33	26.55		
Total	1340.00	38			

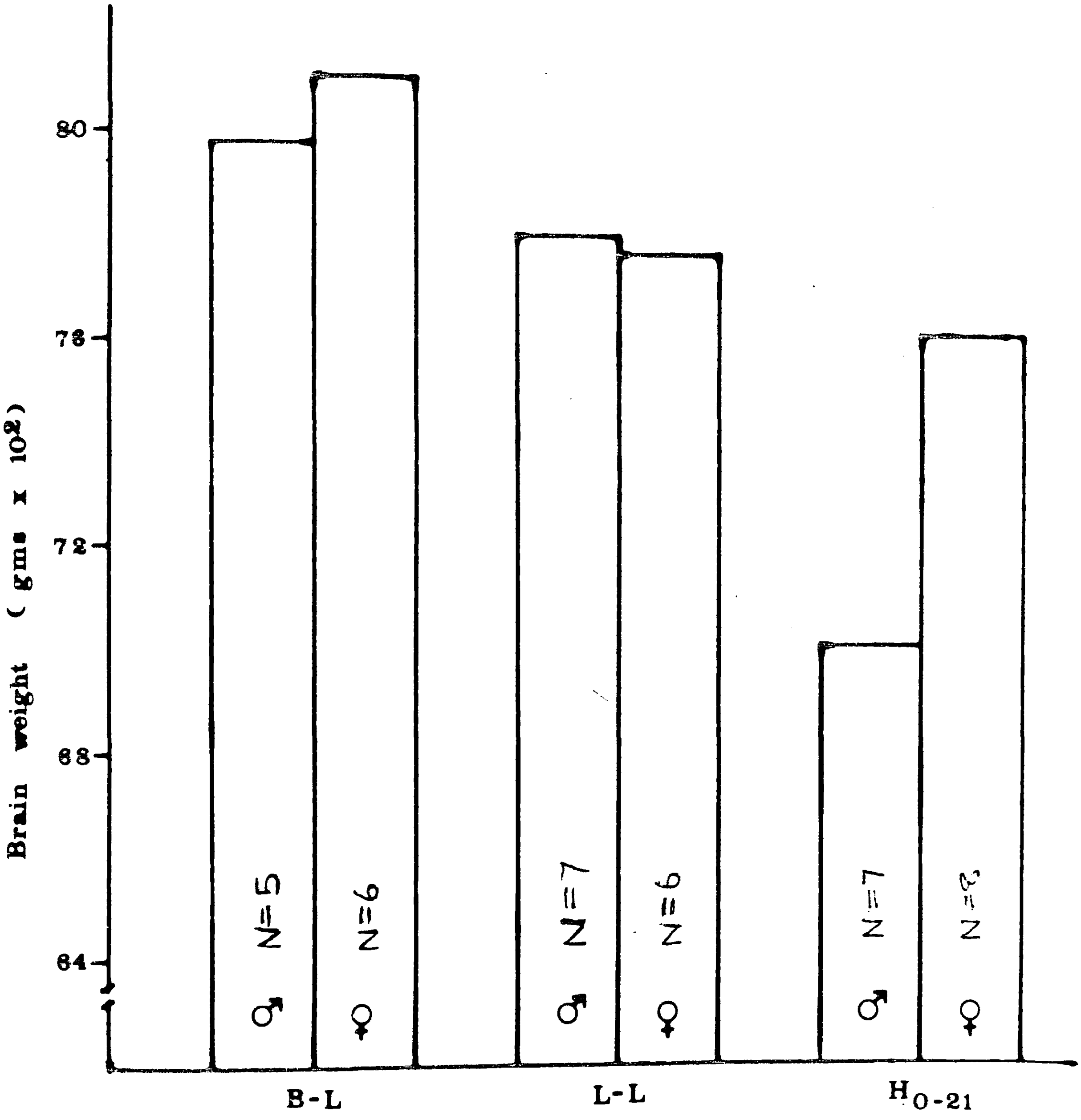
Table 20b: Analysis of brain/body weight ratios in males and females with different early experience (i.e. B-L, L-L, H_{0-21} conditions) N = 20 F, 19 M).

Source	SS	d.f.	mS	F	p
Conditions	680.68	2	340.34	4.03	< 0.05
Sex	411.38	1	411.38	4.87	< 0.025
Sex x Conditions	391.90	2	195.95	2.32	n.s.
Error	2786.33	33	84.43		
Total	4259.59	38			

Figure 15a: Brain weights of animals reared in neonatal conditions.

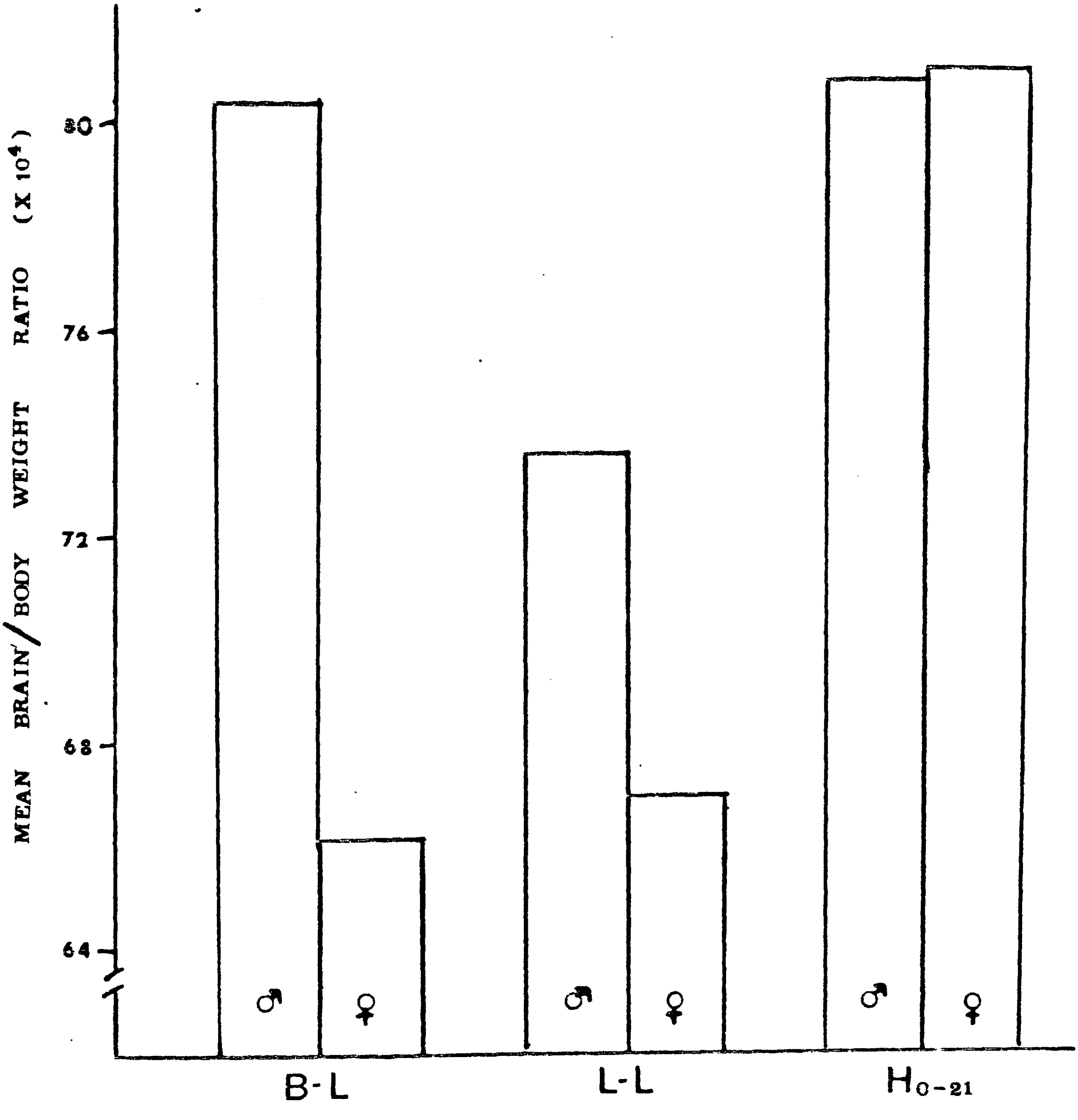
Figure 15b: Brain/body weight ratio of animals reared in neonatal conditions.

Figure 15a



1806.

FIGURE 15b



ii) Adrenal Weight and Plasma Cortisol Levels

The adrenal weights (table 21) show the expected sex difference and this difference is differentially affected, and so exaggerated, by the experimental conditions (figure 16). In the burrow condition the male adrenal weight is increased, whilst in the handled condition both adrenal weights are decreased although the female much more so. It would seem, therefore, that there may be a variable within the experimental design that affects the two sexes differently.

Table 21: Analysis of adrenal weights in males and females with different early experience (N=20♀, 20♂).

Source	SS	d.f.	mS	F	p
Conditions	97.54	2	48.77	5.46	<0.01
Sex	272.34	1	272.34	30.5	<0.001
Sex x Conditions	14.54	2	7.27	<1	
error	303.76	34	8.93		
Total	689.10	39			

The cortisol levels (table 22) give similar results in all conditions for the males, whilst in the females the two experimental conditions give much lower results, with the female control condition plasma cortisol level being comparable with the male values (figure 17).

Table 22: Analysis of plasma cortisol levels in males and females with different early experience (N=20♀, 20♂).

Source	SS	d.f.	mS	F	p
Conditions	19.93	2	9.97	1.46	n.s
Sex	72.14	1	72.14	10.56	<0.01
Sex x Conditions	22.58	2	11.29	1.65	n.s
error	232.35	34	6.83		
Total	353.10	39			

Both these measures were taken in the hope of finding a variable which reflected the supposed difference in stress levels of the various experimental conditions, but neither really shows a continuum in the two sexes, nor do they appear related to each other in any simple manner.

Figure 16. Adrenal weights of animals reared in neonatal conditions.

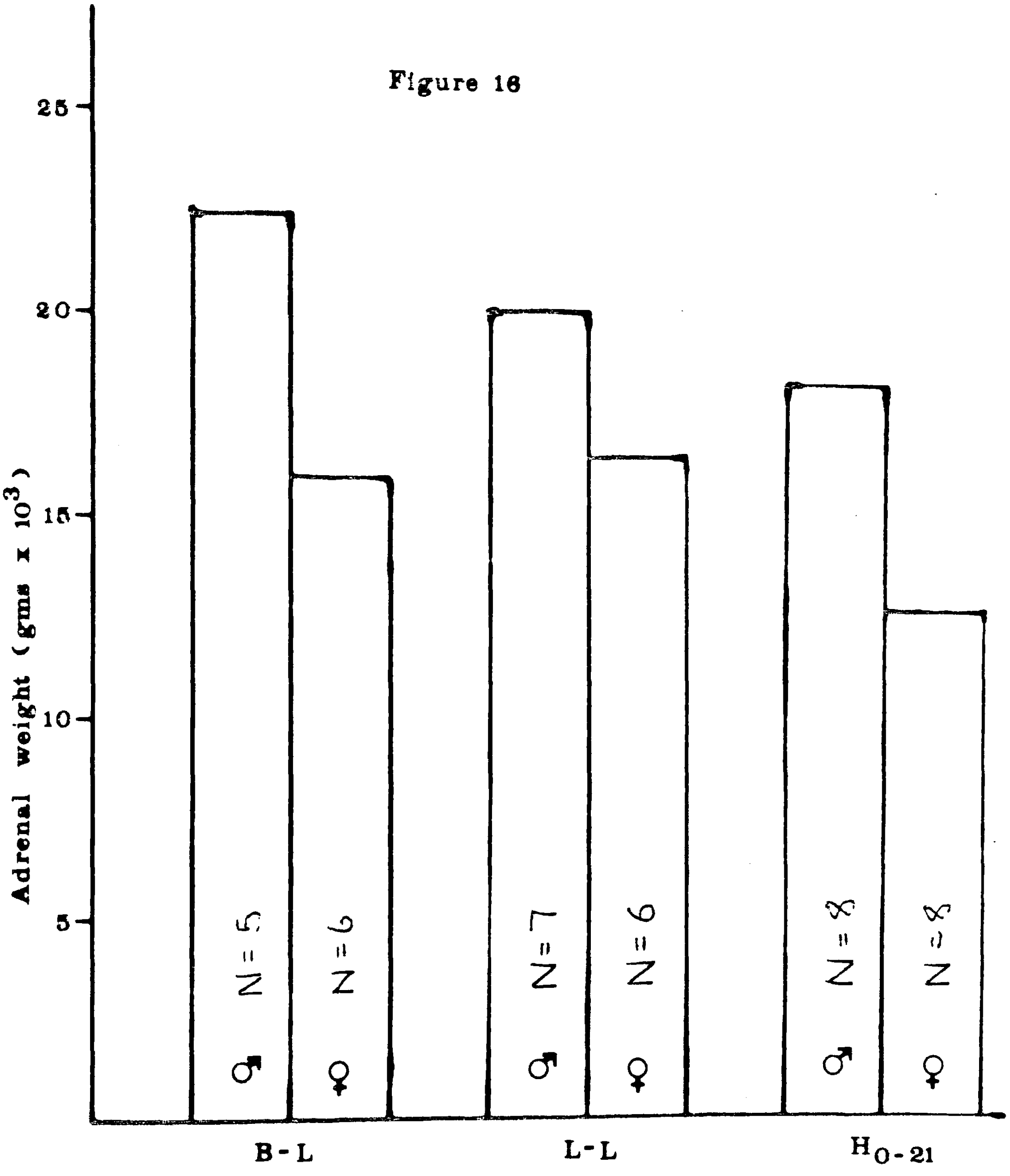
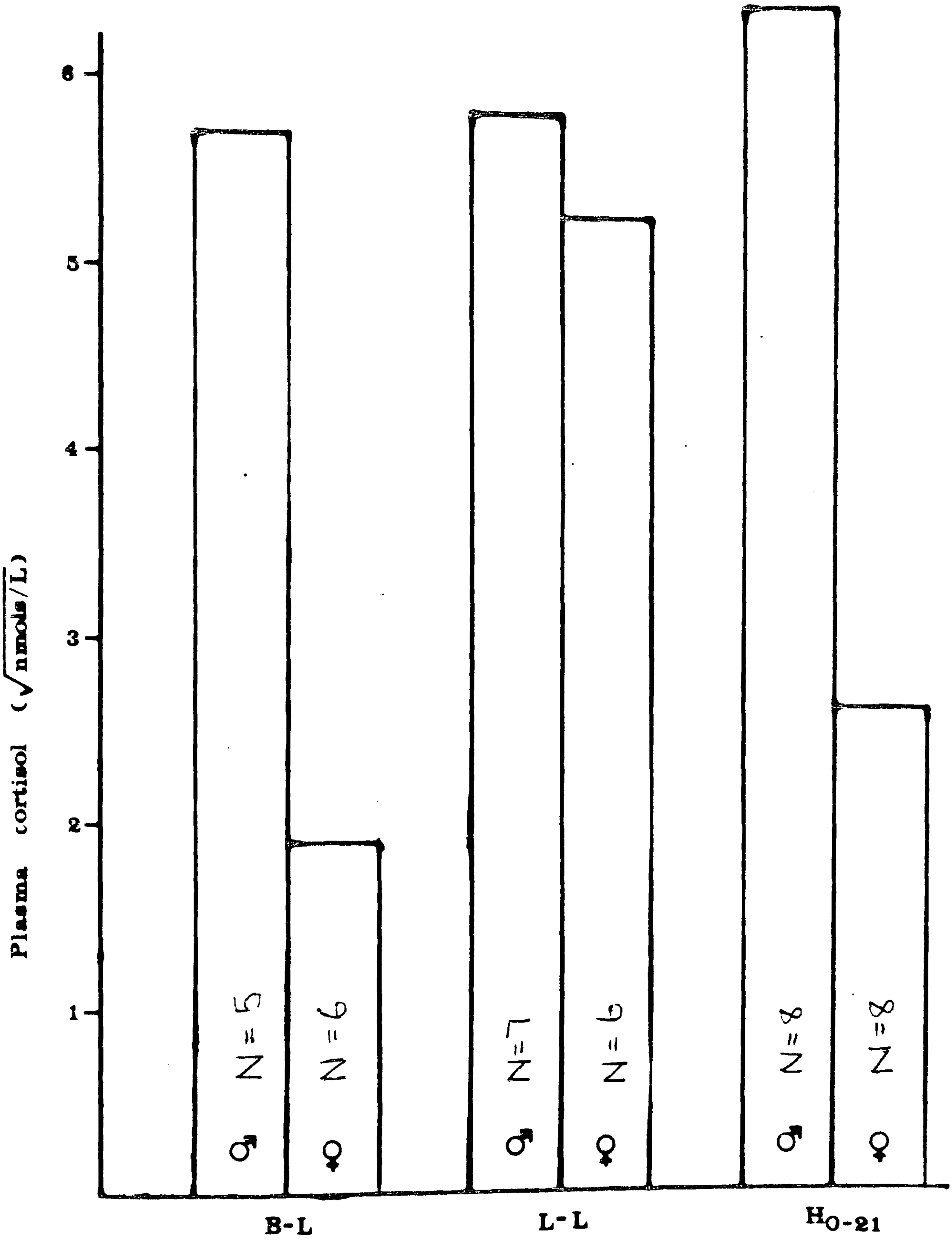


Figure 16

Figure 17. Plasma cortisol levels of animals reared in neonatal conditions.

Figure 17


Plasma cortisol ($\sqrt{\text{nmols/L}}$)
6
5
4
3
2
1
♂ N=5
♀ N=6
♂ N=7
♀ N=6
♂ N=8
♀ N=8
B-L
L-L
H_{O}-21

Discussion

We may now consider these results as a whole in order to obtain an idea of the overall effects produced, and whether those effects were expected in the light of the original hypothesis. It seems useful to consider the two sexes separately in view of the known sexual dimorphism in this species.

The male control animal has good body growth with medium brain growth and adrenal weight, and lowest adrenal output. He is not neophobic in a novel situation, is reactive in the open-field without being emotional and has modest learning ability. By comparison, the burrow-reared male has a medium body growth with high brain growth and heavy adrenals, giving medium output. Again, he is not neophobic in a novel situation, is moderately reactive in the open-field and has good learning ability. This animal may therefore be considered well-adapted to his environment and capable of operating in an optimum way to maximise environmental potential. The handled male, however, has low body weight, small brain growth and small adrenals with high output. He is extremely reactive in the open-field and neophobic with fair learning ability. This male could therefore be considered a neurotic over-reactive organism, whose normal physical and psychological traits have thereby been impaired by the handling procedure.

In the females there are few behavioural differences to be considered, although physically they tend to show the same trends as the males. That is, the burrow reared female has good body growth, large brain, normal adrenals with low output coupled with short reaction times whilst the handled female has low body weight, small brain and small adrenals with a relatively high output.

All these results are basically what would be expected from the experimental hypothesis - all three groups of animals under study showed obvious permanent changes in their adult emotionality, behaviour and physiology as a result of their early experience. All the animals may be said to have adapted within their environment but could not be said to be optimally effective. The advantage of the early burrow is apparent although this may, in part, be due to the selection of this particular species.

Conclusion

The hypothesis predicted that burrow reared animals would show at least signs of stress, less emotionality and improved learning compared with the laboratory reared and handled groups. The comparison between burrow reared and handled animals supports the prediction, at least for this species, and allows one to accept the initial hypothesis that the laboratory environment is over-stimulative for the preweaning organism, and that handling does not make the laboratory more like the natural environment.

SECTION 2 (ii): POSTWEANING CONDITIONS

This section is only presented in summary form as the appropriate figures and alayses are included in section 2 (iii). The two conditions for comparison here are the L-D group (enrichment postweaning, weeks 3-6) and the control group (L-L). Three litters were used in each condition and measures of the dependent variables detailed in chapter V taken. Behavioural observations are included in Appendix A.

Growth:

There is no real difference in growth between the 2 groups at sexual maturity (42 days), nor is there any significant sex difference which would be expected at this age (Swanson, 1967). However, in mature animals there is a highly significant effect for the postweaning condition in that enrichment leads to a greatly increased body weight - particularly in the females (see figure 18). This great increase in body weight was also found in the animals used in the pilot study (see section (i)), although there the effect of body weight change was apparent immediately post-enrichment.

Open-field behaviour

There are no obvious effects on either ambulation or rearing attributable to the enriched environment (see figure 19) compared with the control condition. Increased activity had been expected following the results from the pilot study. However, the scores for ambulation in the novelty box test do give a significant result in that those animals with postweaning enrichment experience are more active (see figure 21 and table 26).

Novelty testing

The results here indicate that enrichment increases reactivity and/or decreases neophobia in that latencies of response to novel objects are decreased. In the males the latency of response is halved for the enriched animals towards both the first and second objects, whilst in the females this increased reactivity is only shown with respect to the first object.

The longer latency to respond to the second object may be a reflection of more rapid habituation to the test situation (figure 22).

Discrimination Learning

By referring to figures 23 and 24 it is obvious that enrichment postweaning allows the animals to learn a simple black/white discrimination more readily, and to complete this task more quickly.

Physiological Data

i) Brain Weight

The enriched environment leads to a decrease in absolute brain weight and in the brain/body ratio for animals reared in that condition postweaning (see figure 25), which is significant on analysis. This is an unexpected result in that normally in the laboratory rat, if an effect is shown, enrichment leads to an increase in brain development.

ii) Adrenal weight and plasma cortisol levels

There is no effect of enrichment on the adrenal weights of these animals (figure 26), whilst the plasma cortisol level is decreased, particularly in the males (figure 27). As no correlation has been established in this species between adrenal gland **size** and function the real effect of an enriched postweaning environment in this respect remains unclear. It may well be that the wider, more natural experience of the enriched animals results in a lower resting level of hormone.

Discussion and Conclusion:

This section is the first report of the effects of a free-enriched environment in the immature golden hamster. Results from the pilot study (section I) on mature animals indicated that increased growth and activity would be a definite result; and the literature would lead one to couple this with probable decreased emotionality, increased learning and increased brain development.

The results, however, are somewhat surprising. Increased growth does occur, but is only apparent in older animals. Increased activity does occur, but again is not apparent immediately in that results for the open-field are insignificant. Only in the later novelty test is the effect of postweaning condition demonstrated. The one clear effect of the enrichment that is in accord with the expected predictions is that of improved, purposeful learning. Physiologically, however, the finding of smaller brain size in the enriched animals is at variance with the expected effect of enrichment, as demonstrated in the laboratory rat, and is difficult to reconcile with this greatly improved learning shown by these animals. A closer histological and biochemical analysis of these brains should prove interesting.

In conclusion, then, we may say that enrichment in this species does have definite, if somewhat, surprising effects. The finding that effects may only be observed in more mature animals demonstrates the far-reaching consequences of early environment, and sheds some light on the finding in rats that enrichment must often be prolonged to obtain physiological effect - it may simply take that length of the animals development in order to be manifested.

SECTION 2(iii): To test the overall hypothesis

In this section an attempt has been made to determine which dependent variables are affected by which independent variable - that is, the preweaning burrow condition and the postweaning desert condition. An examination of the results shows what effects are produced and how they interact. There is also the underlying proposition that one of these environments should be optimal, in that it approximates the natural condition, although the interpretation in this case must to a degree be subjective. This proposition, which underlies the total design of this research, is suggested by Daly's critical analysis of the literature concerning early stimulation of rodents. the conclusion drawn by this review is that typically a preweaning environment should be less stimulating, and a postweaning environment more stimulating, than that provided by a standard laboratory; and that a lack of understanding of a particular species' unique bio-behavioural repertoire has led to innappropriate interpretation of data.

The results treated in this section were obtained in the manner already described (see Section V) and fall into behavioural tests and physiological measures. Behavioural tests were carried out on all animals apart from the discrimination learning, which was done on only a sample of three males from each condition. These data were then analysed using litter means, apart from the learning, which used individual scores. The physiological data (apart from body weight taken at 21, 42, and 90 days) were based on a sample of animals both male and female, taken from each condition and sacrificed at 90 days. They were analysed using raw scores with harmonic means where appropriate. Behavioural observations are detailed in Appendix A.

Growth

Looking first for any effect due to sex, we find the analysis (table 23) gives no significant sex difference at maturity (42 days) although there is a highly significant effect in mature animals (90+ days). There is normally a difference in body weight in the sexes with the female being the heavier, due to the reversal of the normally expected sexual dimorphism, which would be expected to be apparent by sexual maturity (Swanson, 1967) - although strain is also an effective variable (Lawlor, pers.comm). No significant difference is found in the weaning weights of animals in the two preweaning conditions ($F < 1$, $df = 1/10$). A repeated measures analysis of variance revealed little additional information.

Both analyses show significance for the postweaning condition due to the larger growth of the animals in the desert. This increase in weight occurs in both sexes but is particularly apparent in mature females - accounting for at least some of the highly significant sex difference shown in this analysis.

There is no direct effect on body weight as a result of the preweaning condition, although the first analysis shows a significant interaction between pre- and post-weaning conditions - reflected in the second analysis as sex x preweaning and sex x postweaning interactions (see figure 18).

Table 23(a): Analysis of body weight of males and females from different pre- and post-weaning experimental conditions (at 6 weeks). (N = 51 ♀, 43 ♂)

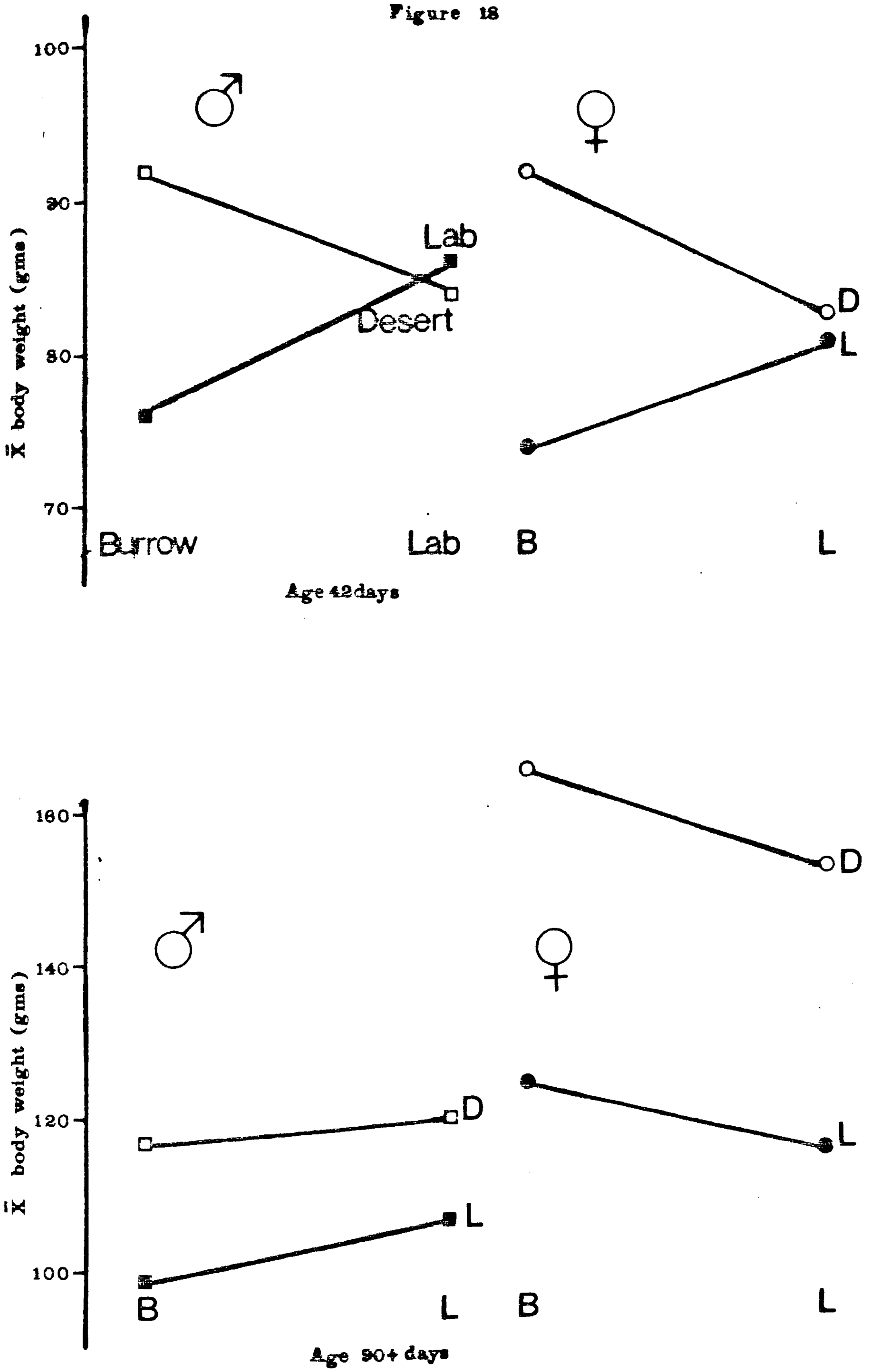
Source	SS	d.f.	mS	F	p
Preweaning condition	0.04	1	0.04	<1	
Postweaning condition	425.04	1	425.04	5.28	<0.05
Pre x Post	425.04	1	425.04	5.28	<0.05
Sex	22.04	1	22.04	<1	
S x Pre	7.04	1	7.04	<1	
S x Post	15.04	1	15.04	<1	
S x Pre x Post	0.05	1	0.05	<1	
Error	1287.33	16			
Total Variance	2181.62	23			

Table 23(b): Analysis of body weight of males and females used in physiological sample, from different pre and post-weaning experimental conditions (at 90+ days). (N = 21 ♀, 19 ♂)

Source	SS	d.f.	mS	F	p
Preweaning condition	62.96	1	62.96	<1	
Postweaning condition	6553.76	1	6553.76	59.79	$\ll 0.001$
Pre x Post	29.3	1	29.3	<1	
Sex	7619.3	1	7619.3	69.51	$\ll 0.001$
S x Pre	543.66	1	543.66	4.96	<0.05
S x Post	1199.48	1	1199.48	10.94	<0.01
S x Pre x Post	0.00	1	0		
Error	3507.64	32	109.61		
Total Variance	20555.90	39			

Figure 18. Body weights of sexually mature (42 days) and mature (90+ days) animals showing the influences of the pre- and post-weaning environments.

Figure 18


100
90
80
70
X̄ body weight (gms)
♂
♀
Lab
Desert
D
L
Burrow
Lab
B
L
Age 42days
160
140
120
100
X̄ body weight (gms)
♂
♀
D
L
D
L
B
L
B
L
Age 90+ days

At maturity the effect of the desert experience is not fully expressed as it is affected by the underlying preweaning experience. By 90 days the postweaning desert has led to a dramatic increase in weight, accentuated by an early burrow environment in the females. It seems unrealistic to attribute this increase to either a greater availability of food or an increased activity level as has been postulated (see Appendix A). Rather the preweaning condition of the organism appears to prime the animal to react and develop within its future situation; and that the total pre-adult environment is exerting an influence throughout the organism's lifespan.

Overall, the growth curves obtained fit standard data (i.e. Farris, 1950) well, with some variation that could be attributed to strain and dietary differences with the females in conditions L-D and B-D showing accelerated growth in particular (see figure 19).

<u>Open-field Behaviour</u>

The open-field testing was carried out on all subjects for four consecutive days and the data for ambulation and rearing analysed separately.

The analysis was carried out separately for males and females as previous work, particularly that by Swanson, suggested that sex differences are normally found in hamsters. The sex differences in these results are not in fact very large ($F < 1$, d.f. = 1/5) - this may be due to strain differences or the experimental conditions have served to over-ride sex differences which may have otherwise occurred. It is interesting to note that an experiment carried out by Swanson (1969) to determine the effect of prior experience of the test situation (this prior experience occurring whilst the animals were still immature) also resulted in a loss of sex differences in the mature animals. Possibly the early experiences in this research have operated in a similar manner to alter the animals' response to a novel situation.

In the females there is no significant result for ambulation in the open-field other than the expected trials effect. The males, however, do show a significant trials x pre-weaning condition effect due to the difference in the scores of the burrow reared animals, particularly at the beginning of the trials (see table 24 and figure 20).

Figure 19. Growth curves of litters reared in different
environmental conditions: (a) males (N = 43).
(b) females (N = 51).

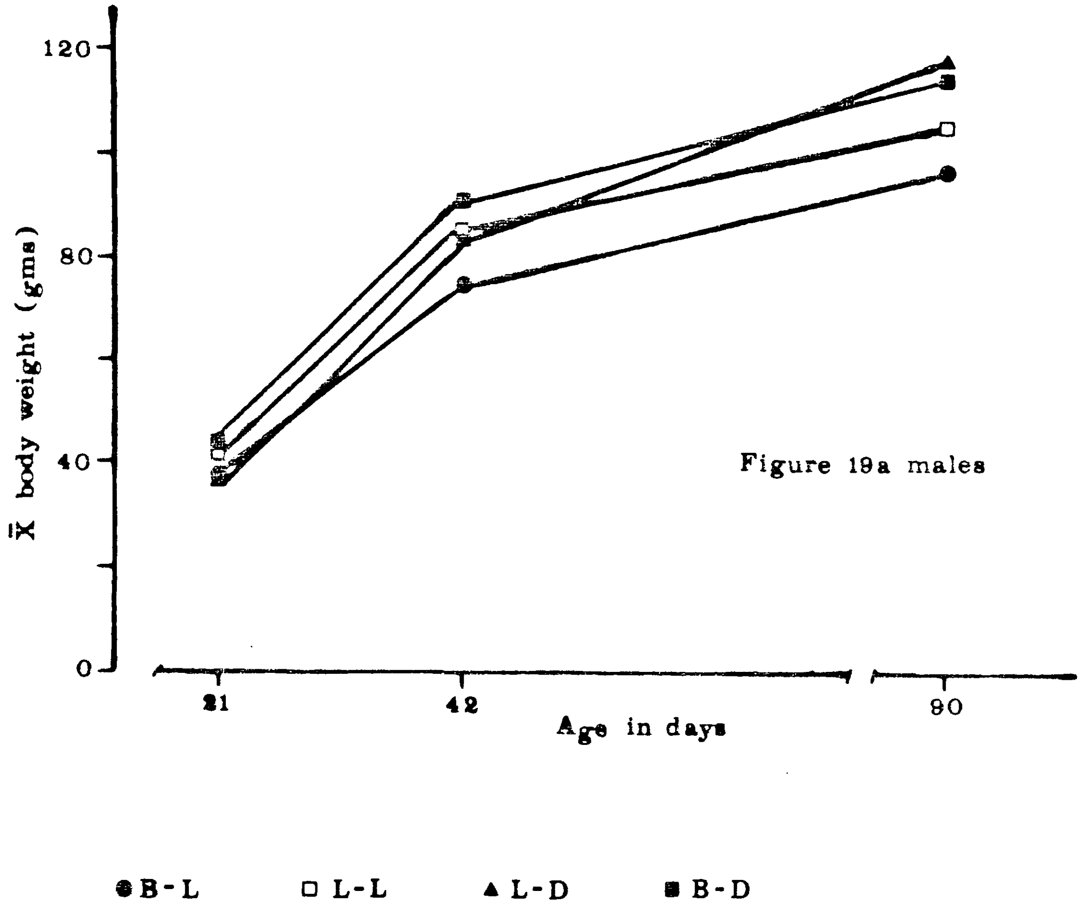


Figure 19a males

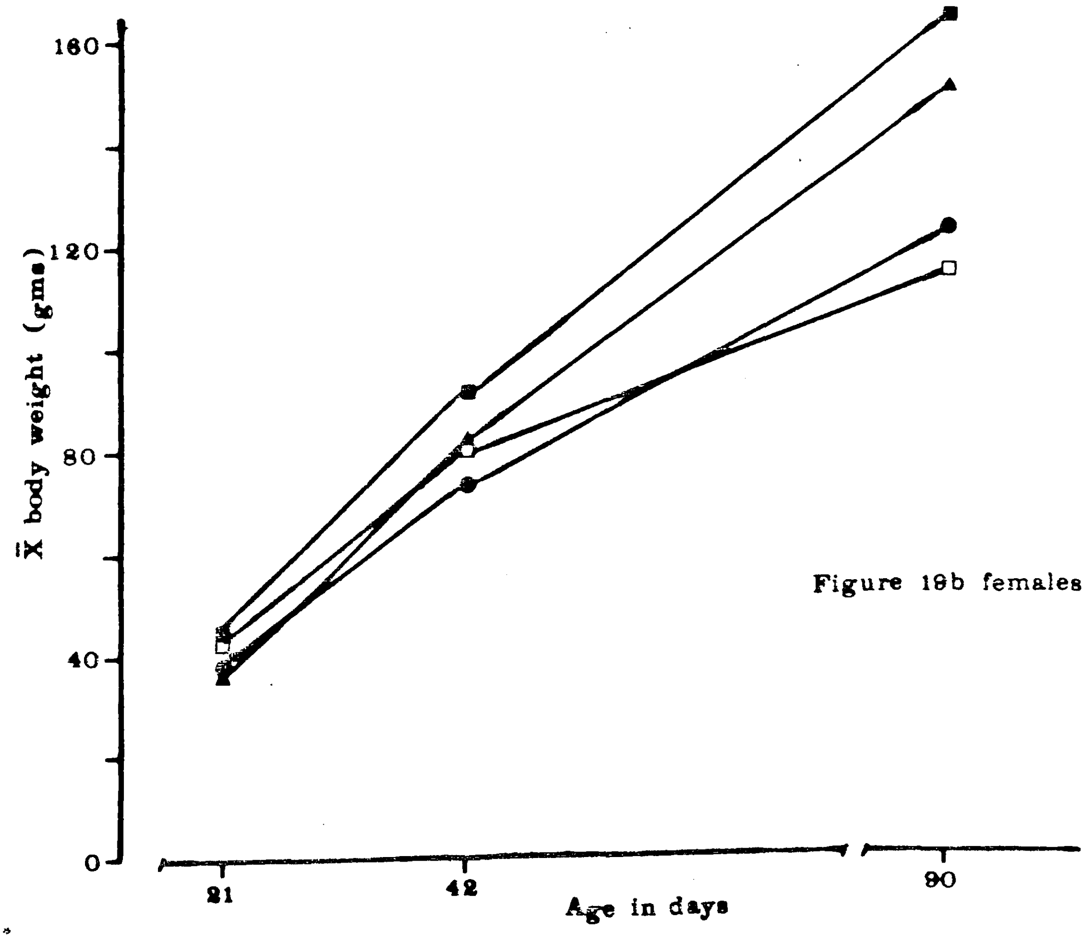


Figure 19b females

Table 24(a): Repeated measures analysis of variance of open-field ambulation in males (3 litters/condition).

Source	SS	d.f.	mS	F	p
Preweaning condition	46.02	1	46.02	<1	
Postweaning condition	3.52	1	3.52	<1	
Pre x Post	1.69	1	1.69	<1	
error	2820.00	8	352.50		
Total subjects	2871.23	11			
Trials	2362.40	3	787.47	32.25	<0.001
T x Pre	414.06	3	138.02	5.65	<0.01
T x Post	179.56	3	59.85	2.45	<0.1
T x Pre x Post	97.73	3	32.58	1.33	n.s
error	586.00	24	24.42		
Total	6510.98	47			

Table 24(b): Repeated measures analysis of variance of open-field ambulation in females (3 litters/condition).

Source	SS	d.f.	mS	F	p
Preweaning condition	357.52	1	357.52	2.30	n.s
Postweaning condition	180.19	1	180.19	1.16	n.s
Pre x Post	123.52	1	123.52	<1	
error	1241.83	8	155.23		
Total subjects	1903.06	11			
Trials	4578.73	3	1526.24	33.6	$p<0.001$
T x Pre	58.23	3	19.41	<1	
T x Post	35.56	3	11.85	<1	
T x Pre x Post	64.56	3	21.52	<1	
error	1090.17	24	45.42		
Total	7730.31	47			

Figure 20. Open-field ambulation of litters reared in different environmental conditions: total sections entered

(a) males (N = 43)

(b) females (N = 51)

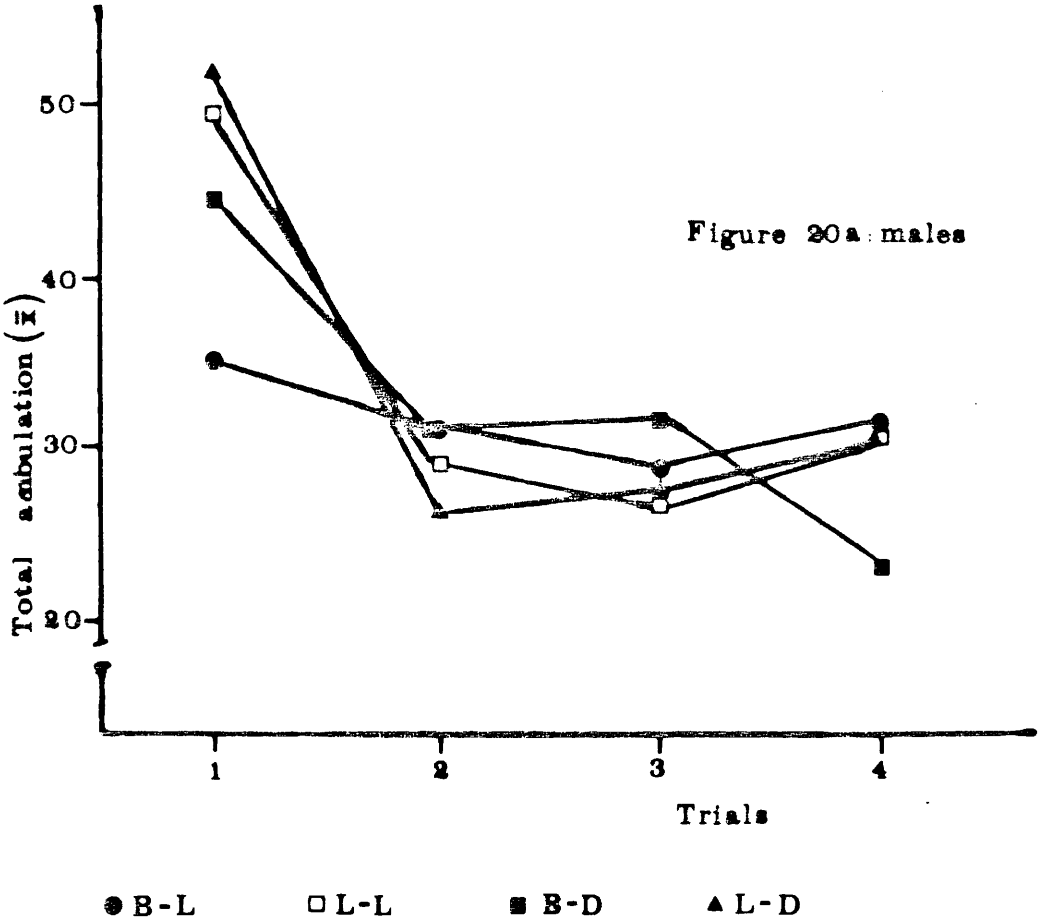


Figure 20a: males

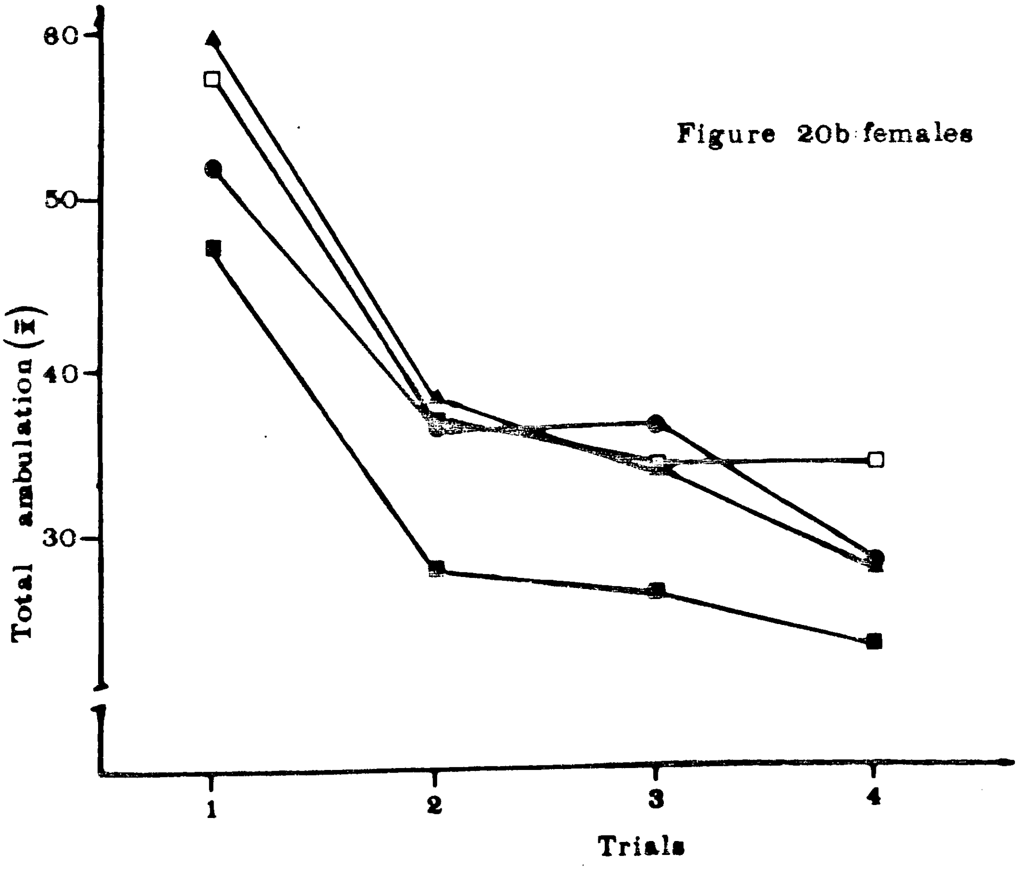


Figure 20b: females

This depression in scores, especially in the B-L group, on day 1 may be interpreted as an increased emotionality (see Whimbey and Denenberg) followed by normal levels of exploration. In this group, it is more appropriate to attribute this decreased ambulation on day 1 as an adaptive response to a novel environment rather than reflecting some disadvantage in emotional terms. Those animals reared in the deserts postweaning tend to have lower levels of ambulation on later trials, giving the trials x postweaning interaction significance at the 10% level - indicating their habituation and satiation with the test situation.

The rearing scores give the expected significant result for trials on analysis in both sexes (see table 25) and also an interactive effect of trials x preweaning condition in the males due, again, to the depression of scores of the B-L group on day 1.

Table 25(a): Repeated measures analysis of variance of open-field rearing in males(3 litters/condition).

Source	SS	d.f.	mS	F	p
Preweaning condition	42.19	1	42.19	<1	
Postweaning condition	9.19	1	9.19	<1	
Pre x Post	46.02	1	46.02	<1	
error	1726.33	8	215.79		
Total subjects	1823.73	11			
Trials	291.73	3	97.24	13.64	<0.001
T x Pre	50.23	3	16.74	2.35	<0.1
T x Post	33.56	3	11.19	1.57	n.s
T x Pre x Post	30.73	3	10.24	1.44	n.s
error	171.00	24	7.13		
Total Variance	2400.98	47			

Table 25(b): Repeated measures analysis of variance of open-field rearing in females(3 litters/condition).

Source	SS	d.f.	mS	F	p
Preweaning condition	114.09	1	114.09	<1	
Postweaning condition	3.00	1	3.00	<1	
Pre x Post	1.33	1	1.33	<1	
error	1316.5	8	164.56		
Total subjects	1434.92	11			
Trials	391.75	3	130.58	9.16	<0.001
T x Pre	32.08	3	10.69	<1	
T x Post	18.5	3	6.17	<1	
T x Pre x Post	24.5	3	8.17	<1	
error	342.17	24	14.24		
Total Variance	2243.92	47			

The standard open-field test therefore failed to give much information except with the males in the preweaning condition. There was, however, a similar type of ambulation score taken during the adaptation phase of the test for response to novel objects. Although this is not a standard open-field test (it being a much smaller field - see plates 4 and 5 for comparison) it does show the females ambulated much more than the males and that both sexes from the desert postweaning condition showed higher ambulation (see table 26 and figure 21).

Table 26: Analysis of male and female ambulation in novelty box.
(3 litters/condition)

Source	SS	d.f.	mS	F	p
Preweaning condition	4.16	1	4.16	<1	
Postweaning condition	42.66	1	42.66	5.02	<0.05
Pre x Post	0.18	1	0.18	<1	
Sex	266.66	1	266.66	31.37	$\leqslant 0.001$
S x Pre	1.51	1	1.51	<1	
S x Post	2.68	1	2.68	<1	
S x Pre x Post	13.48	1	13.48	1.59	n.s
error	136,0	16	8.5		
Total Variance	467.33	23			

Figure 21. Novelty test ambulation of litters reared in different environmental conditions: (a) males

(b) females

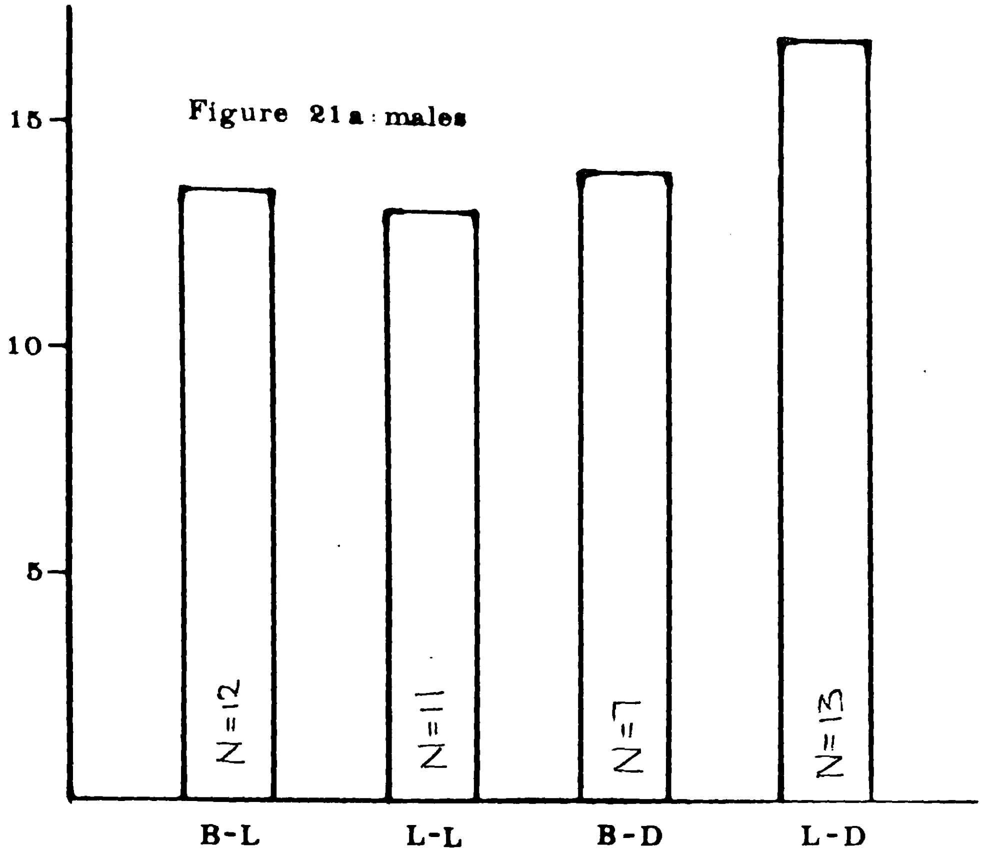


Figure 21a: males

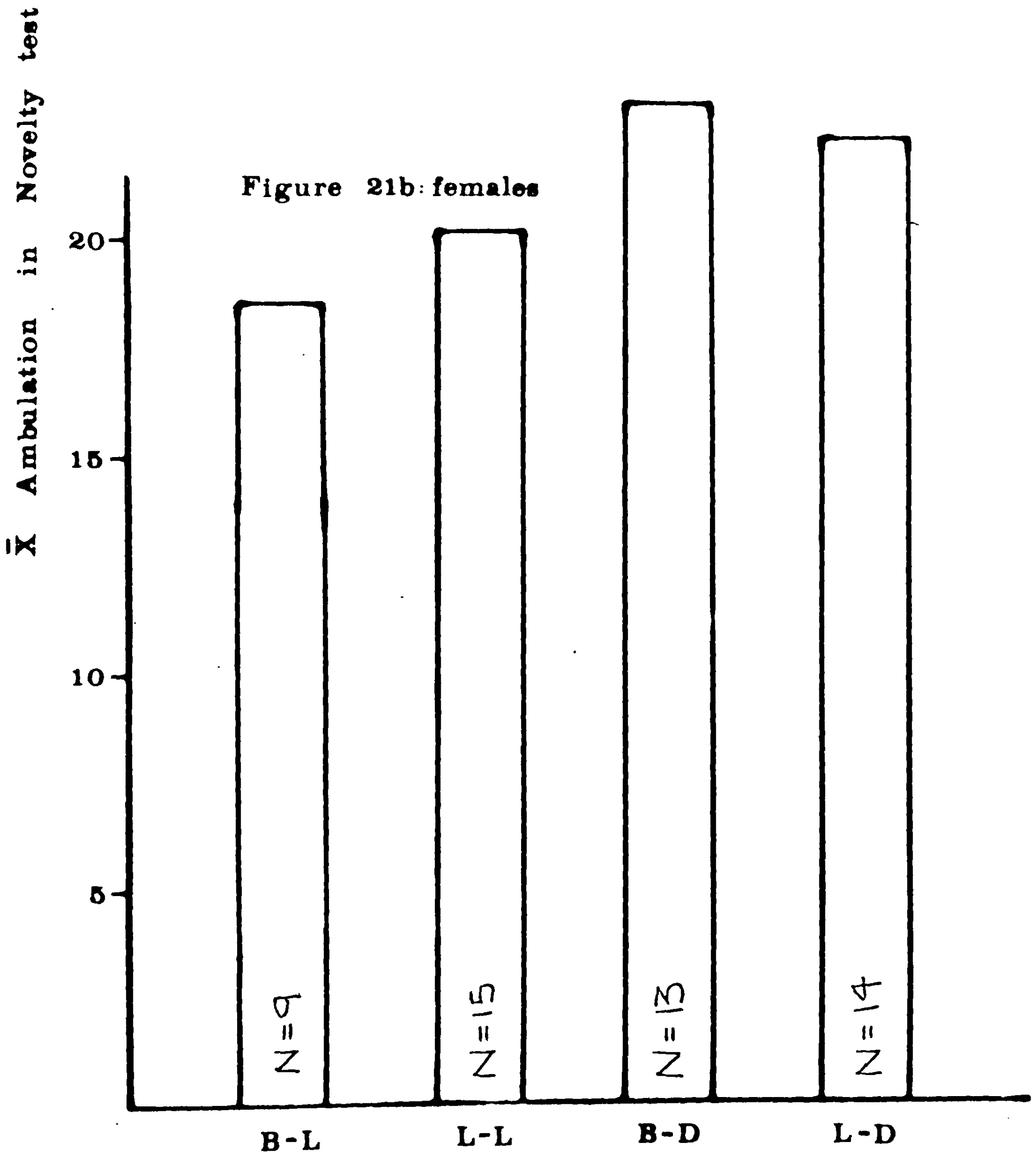


Figure 21b: females

Novelty Testing

This test had essentially two parts - the first the latency to respond to the novel objects, and the second the time spent investigating any of the objects. This second measure of time on object was found to be so varied as to be meaningless on analysis although the reaction time (the time to respond to and approach the object) showed considerable result (table 27).

Table 27(a): Latency to respond to novel objects, males (N=43).

Source	SS	d.f.	mS	F	p
Preweaning condition	450.67	1	450.67	7.32	<0.05
Postweaning condition	337.50	1	337.50	5.48	<0.05
Pre x Post	2.66	1	2.66	<1	
error	492.67	8	61.58		
Total Subjects	1283.50	11			
Trials	1320.17	1	1320.17	31.25	<0.001
T x Pre	352.66	1	352.66	8.35	<0.025
T x Post	280.16	1	280.16	6.63	<0.05
T x Pre x Post	150.01	1	150.01	3.55	n.s
error	338.00	8	42.25		
Total	3724.50	23			

Table 27(b): Latency to respond to novel objects, females (N = 51)

Source	SS	d.f.	mS	F	p
Preweaning condition	0.38	1	0.38	<1	
Postweaning condition	459.38	1	459.38	1.22	n.s
Pre x Post	198.37	1	198.37	<1	
error	3017.33	8	377.17		
Total Subjects	3675.46	11			
Trials	4030.04	1	4030.04	12.59	<0.01
T x Pre	5.04	1	5.04	<1	
T x Post	590.04	1	590.04	1.84	n.s
T x Pre x Post	165.38	1	165.38	<1	
error	2560.00	8	320.00		
Total	11025.96	23			

In the females the only significant result for latency to response was a trials effect reflecting the slower response to the second object than the first, especially in those animals from the desert postweaning condition. In the males there is an abundance of significant effects, with the major one again being the trials effect of slower response to the second object than the first. Both the desert and the burrow produce an effect of increased reactivity in the laboratory reared animal to both the first and the second object. When these two rearing conditions are combined (B-D) they do not affect the animals' initial reactivity but do dramatically alter the reactivity to the second object. This is a very different pattern of response behaviour than that shown in any of the other three conditions, in that these males respond more quickly to the second than the first object, although they respond quickly to both. This result might be explained by the action of the experimental conditions on separate functional systems - that is, the desert seems to increase levels of ambulation whilst the burrow may increase arousal (figure 22).

With reference to the table of analysis of variance, if it were not for this very conspicuous interaction it would be doubtful if the other results would be significant although they do reach criterion level. It is a case where the interaction may invalidate the significant results for the main variables.

Discrimination Learning

Again we have a trials effect showing the largest source of variance, indicating that the animals learnt the discrimination. This dramatic effect is due to the fact that such a simple discrimination was used and the 'ceiling' for that learning ability was attained very quickly. There is also a small straightforward effect from the post-weaning desert condition indicating that these animals can benefit from an enriched environment with regard their learning ability (table 28).

Figure 22. Latency to response to objects in novelty test of litters reared in different environmental conditions:

(a) males (N=43)

(b) females (N=51)

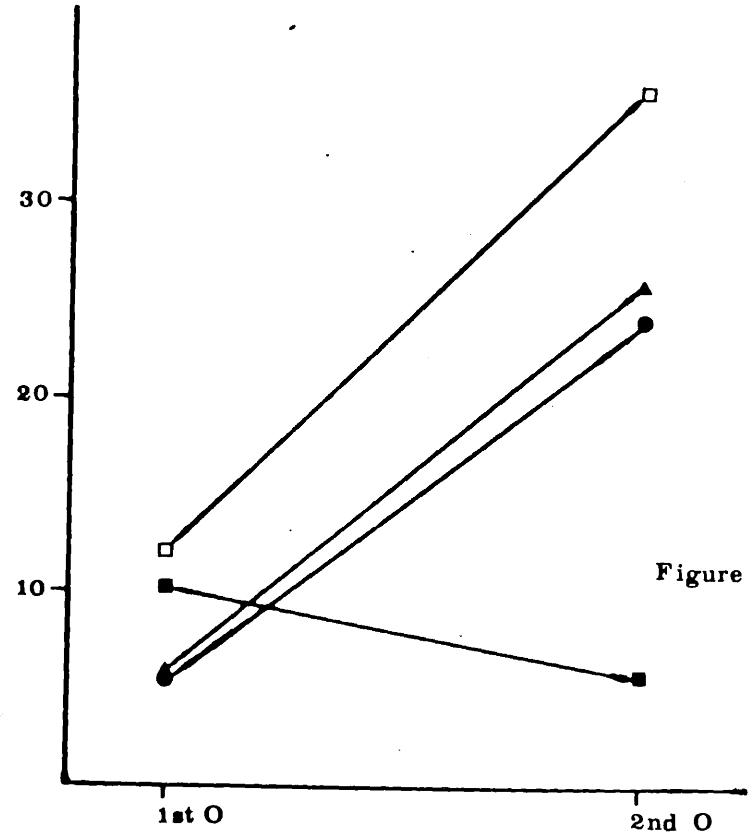


Figure 22a: males

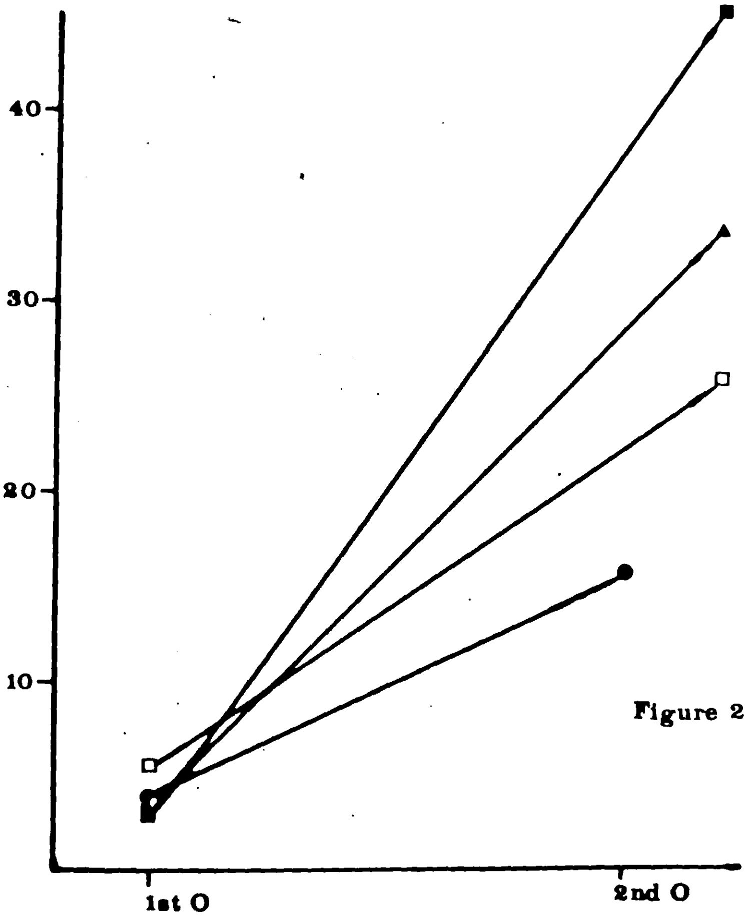


Figure 22b: females

Table 28: Analysis of variance of correct number of responses made in discrimination learning trials (3 males only/condition).

Source	SS	d.f.	mS	F	p
Within subjects					
Preweaning condition	0.02	1	0.02	<1	
Postweaning condition	9.19	1	9.19	3.44	=0.1
Pre x Post	42.19	1	42.19	15.8	<0.01
Error	21.33	8	2.67		
Total Subjects	72.73	11			
Between subjects					
Trials	519.4	3	173.13	56.58	<0.001
T x Pre	0.06	3	0.02	<1	
T x Post	10.22	3	3.41	1.11	n.s
T x Pre x Post	22.23	3	7.41	2.42	<0.1
Error	73.34	24	3.06		
Total variance	697.98	47			

The other significant result is the large interaction between the pre- and post-weaning conditions, which is also reflected in the higher order interaction, T x Pre x Post. The most efficient learning group are those males in the L-D group and the least efficient were the control (L-L) group. Those in the burrow were slightly more efficient than those in the lab, although those who subsequently went into the desert (B-D) were less efficient than those who subsequently went into the lab (B-L) condition (figure 23). This interaction suggests that prior experience and early rearing conditions are important but that the interaction, rather than any of the conditions on their own, is the critical variable. In other words, a situation may be beneficial or adverse for any given animal but the overall effect would be dependent on that particular animals' constitution and experience.

Trial times for this discrimination learning show a dramatic increase in the rate of acquisition as a result of both the early burrow and the postweaning desert conditions (figure 24 and table 29).

Figure 23. Discrimination learning curves of males reared in different environmental conditions: total number of correct responses. (N = 12)

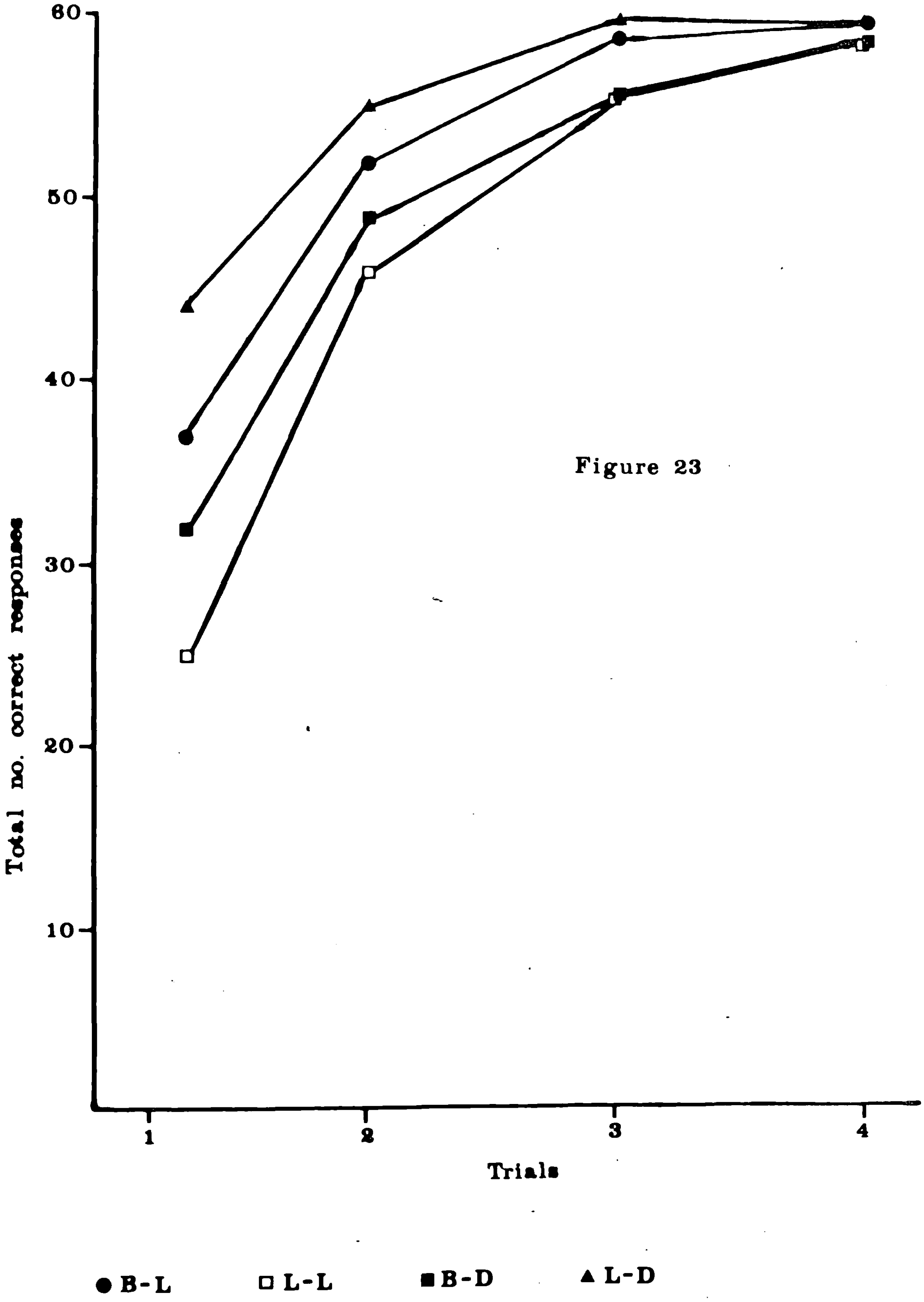
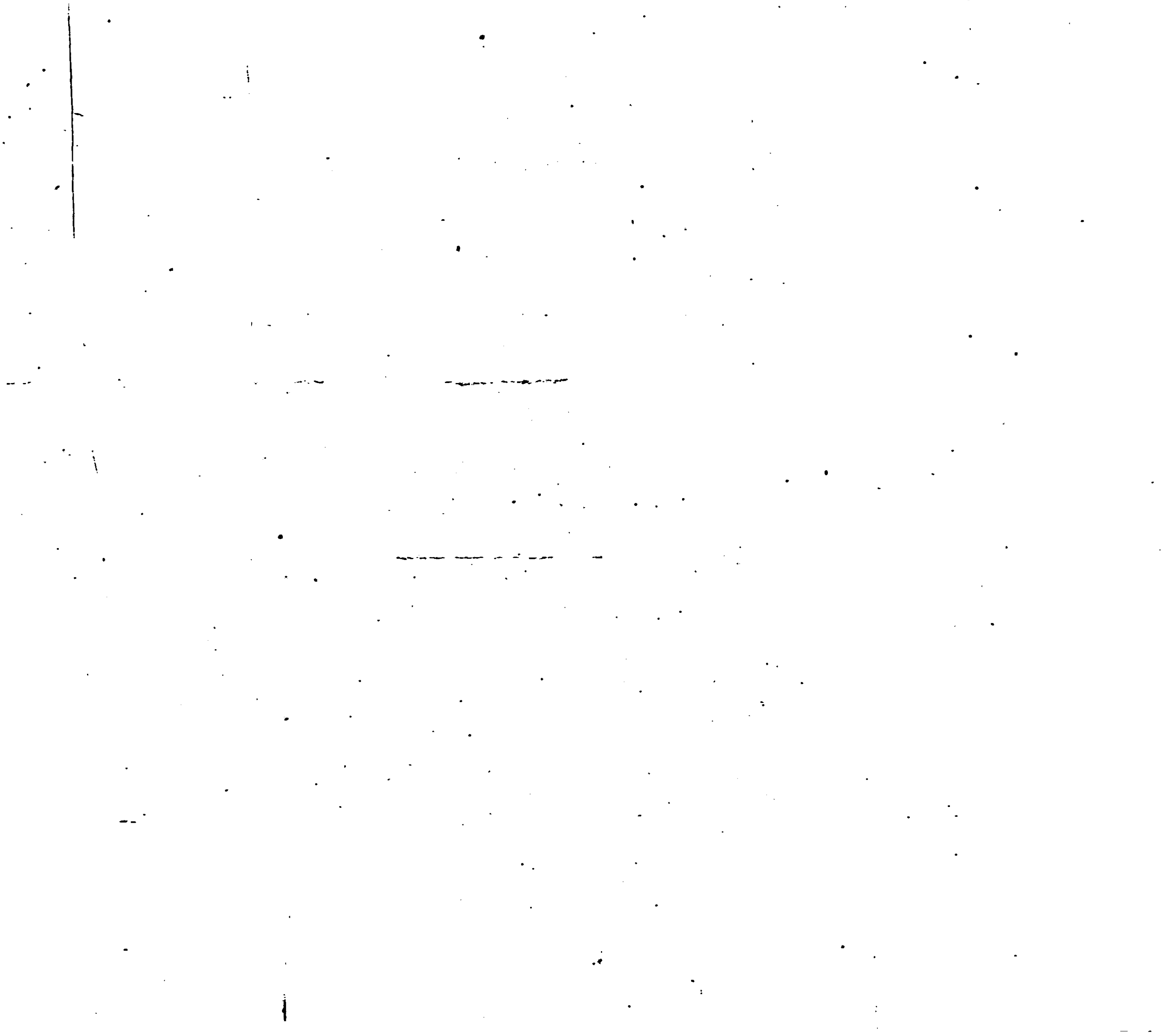


Figure 23
60
50
40
30
20
10
Total no. correct responses
1
2
3
4
Trials
● B-L
□ L-L
■ B-D
▲ L-D

Figure 24. Times taken for discrimination learning trials by males reared in different environmental conditions. (N= 12)



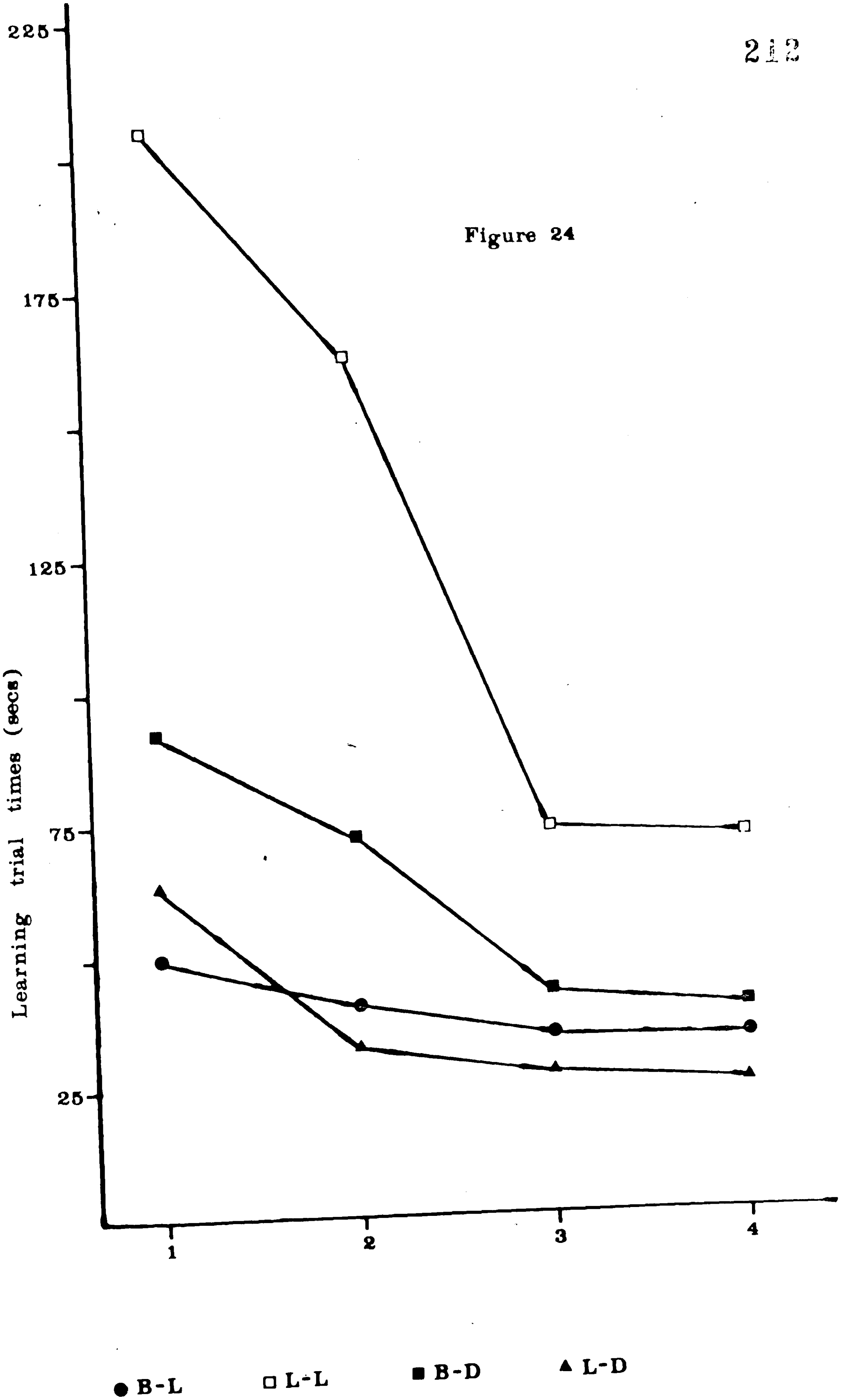


Figure 24

Table 29: Analysis of variance of discrimination learning trial times (3 males only/condition).

Source	SS	d.f.	mS	F	p
Within subjects					
Preweaning conditions	12416.33	1	12416.33	5.78	<0.05
Postweaning conditions	14490.75	1	14490.75	6.75	<0.05
Pre x Post	38646.75	1	38646.75	18.00	<0.01
Error	17175.34	8	2146.92		
Total subjects	82729.17	11			
Between subjects					
Trials	29931.17	3	9977.06	29.04	<0.001
T x Pre	5519.83	3	1839.94	5.36	<0.01
T x Post	2703.75	3	901.25	2.62	<0.1
T x Pre x Post	10857.42	3	3619.14	10.53	<0.001
Error	8245.33	24	343.56		
Total Variance	139986.67	47			

In sum, on the behavioural observations, there is little effect on the females for open-field or response to novelty. Therefore one must conclude there is little behavioural consequence in the females of either the pre- or post-weaning conditions that we can demonstrate with these measures. This is not unusual as many early experience experiments have shown effects in the male undemonstrated in the female. It is difficult tp reconcile, however, with Swanson's statement '....that female hamsters are more susceptible than males to environmental influences...' (1969).

In the males there are behavioural effects on open-field ambulation, response to novel objects and on discrimination learning which are, in the main, interactive effects. The results are such that both the pre- and post-weaning conditions affect the animals differentially with respect to the prior condition and experience. The preweaning condition seems important in the formation of an animal's responsiveness whilst the postweaning condition is more concerned with the effective consequence of that responsiveness.

Generally the postweaning enriched environment for the hamster had similar effects as those attributed to an enriched environment for the rat; that is, there was increased ambulation, probable decreased emotionality, increased reactivity and improved learning ability.

However, the only result that really allows for simple interpretation is that of discrimination learning where it is obvious that the condition most favouring rapid acquisition of a simple discrimination is the ordinary laboratory condition followed by a free enriched environment postweaning.

Physiological Data

i) Brain Weight

The effect on brain weight due to sex almost approaches the 10% level, due to the females having larger brains than the males - an effect which is not simply due to the differences in body weight, as verified by referring to the brain/body weight ratios (Table 30b and Figure 25b).

There is a significant effect (Table 30a) due to the postweaning desert condition which decreases brain weight, particularly in the males. The females tend to show an increase in brain weight due to the preweaning burrow condition (see figure 25a). There is absolutely no evidence that an enriched environment leads to increased cerebral growth in this species as has been demonstrated for the rat (Ferchmin, Bennett and Rosenzweig, 1975).

Table 30a: Analysis of brain weights from males and females reared in different early environmental conditions ($F = 2.87$, d.f. = 1/32, $p = 0.1$). (N = 21 F, 19 M)

Source	SS	d.f.	mS	F	p
Preweaning condition	35.2	1	35.2	< 1	
Postweaning condition	140.8	1	140.8	3.54	< 0.1
Pre x Post	8.8	1	8.8	< 1	
Sex	107.8	1	107.8	2.71	n.s.
S x Pre	55.0	1	55.0	1.38	n.s.
S x Post	107.8	1	107.8	2.71	n.s.
S x Pre x Post	19.8	1	19.8	< 1	
Error	1271.44	32	39.73		
Total Variance	1689.78	39			

Table 30b: Analysis of brain/body weight ratio for males and females reared in different early environmental conditions (i.e. B-L,L-L,B-D,L-D conditions)(N=21F,19M)

Source	SS	d.f.	mS	F	p
Preweaning condition	9.20	1	9.2	< 1	
Postweaning condition	2584.03	1	2584.03	47.27	< 0.001
Pre x Post	30.81	1	30.81	< 1	
Sex	979.64	1	979.64	17.92	< 0.001
Sex x Pre	19.07	1	19.07	< 1	
Sex x Post	0.06	1	0.06	< 1	
S x Pre x Post	51.55	1	51.55	< 1	
Error	1749.2	32	54.66		
Total	5870.0	39			

Figure 25a. Brain weights of animals reared in different early environmental conditions.

Figure 25b. Brain/body weight ratios of animals reared in different early environmental conditions.

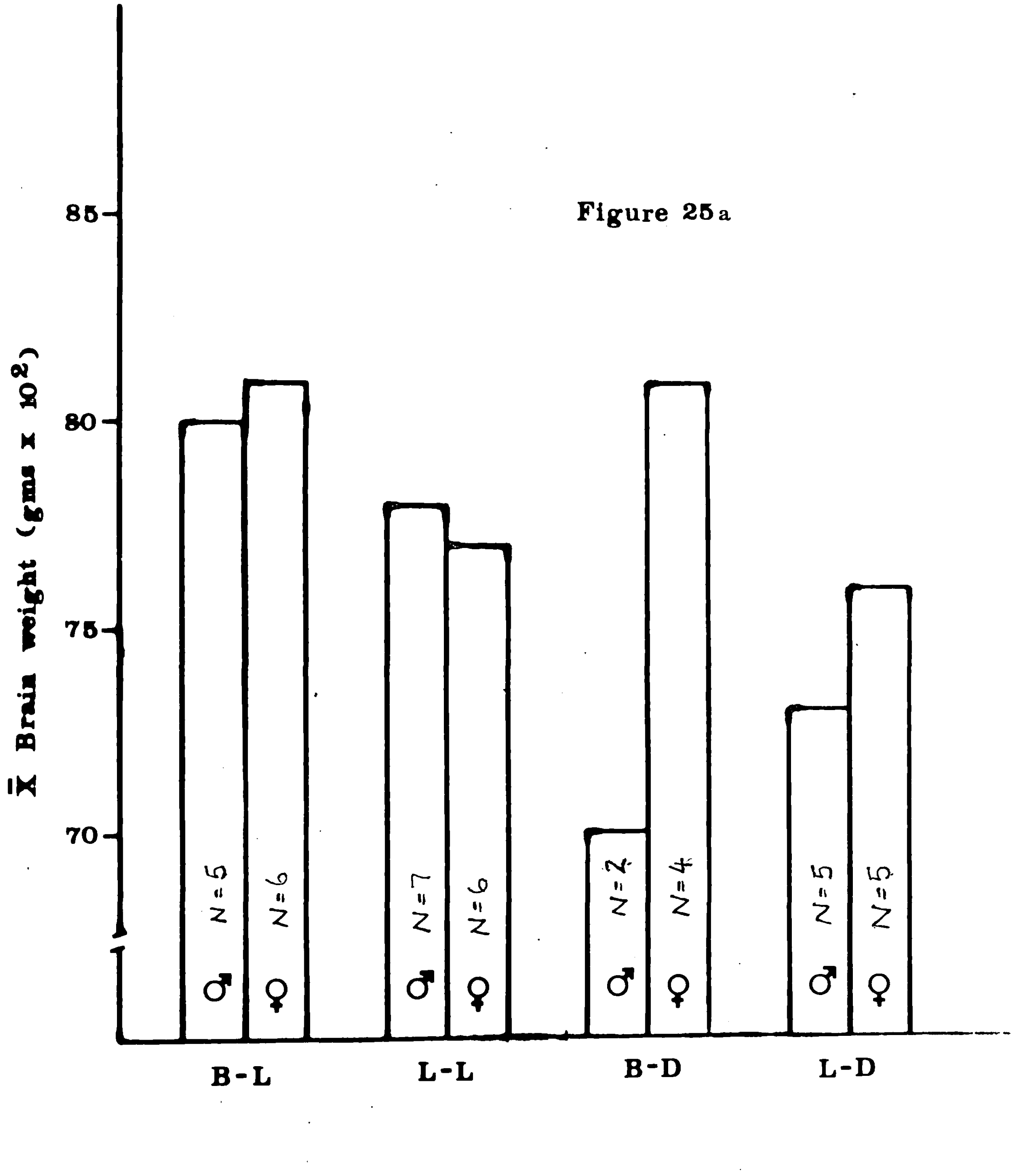
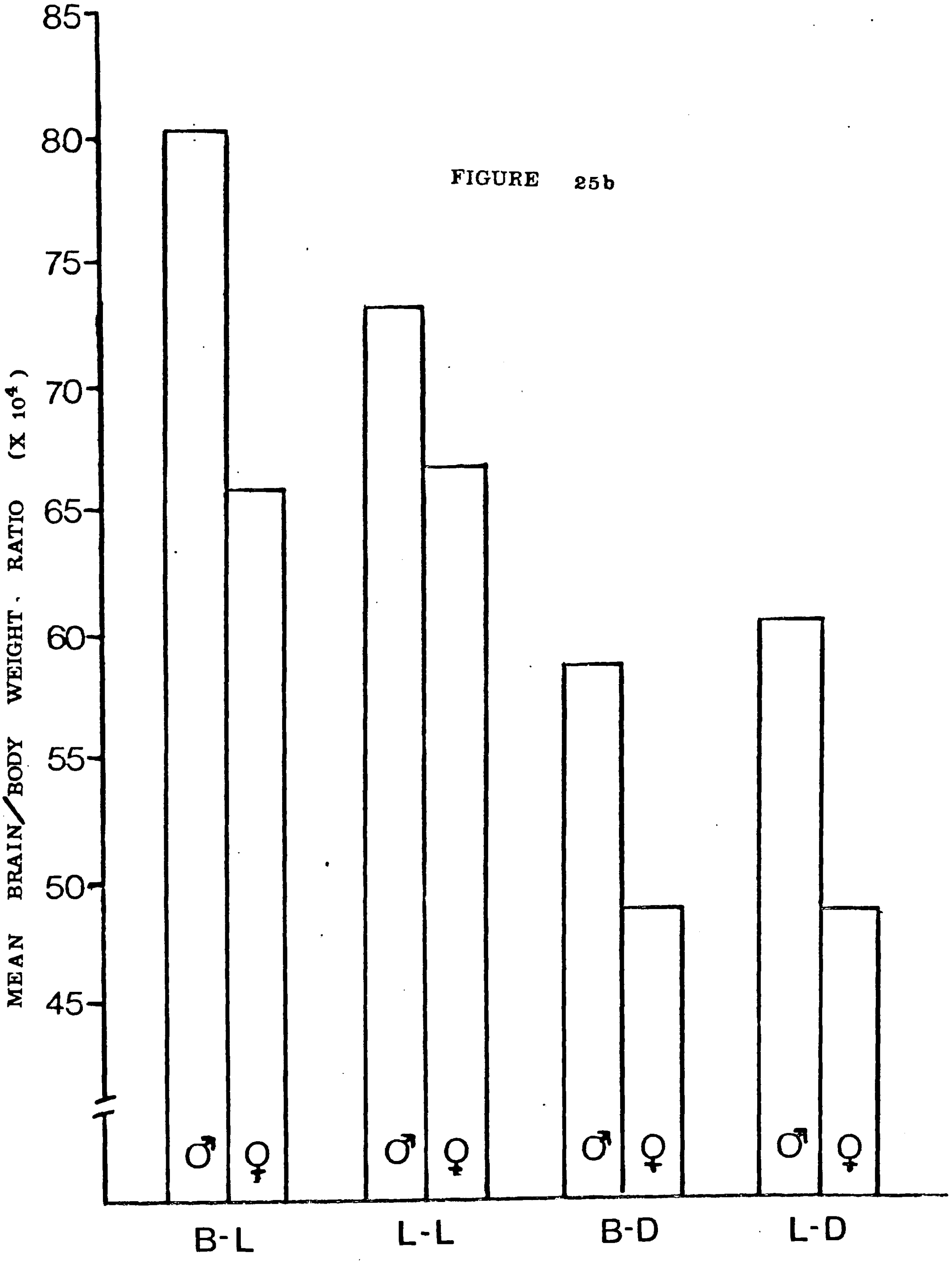

X̄ Brain weight (gms x 10²)
85
80
75
70
N=5
N=6
N=7
N=6
N=2
N=4
N=5
N=5
♂
♀
♂
♀
♂
♀
♂
♀
B-L
L-L
B-D
L-D

Figure 25a

FIGURE 25b


85
80
75
70
65
60
55
50
45
MEAN BRAIN/BODY WEIGHT. RATIO (X 10^4)
♂
♀
♂
♀
♂
♀
♂
♀
B-L
L-L
B-D
L-D

The results of the analysis can almost entirely be explained by the dramatic reduction in brain weight in those males reared in the B-D condition. Again this is not reflected in body weight although there is some indication of poorer cognitive ability in this group, despite the fact there is no demonstration of a simple relation between brain weight and cognitive ability. It is thought that the transition from the burrow condition to the desert condition may have constituted a trauma for these animals which could be reflected here and may account for some of the interactive effects already demonstrated.

ii) Adrenal weight and plasma cortisol levels

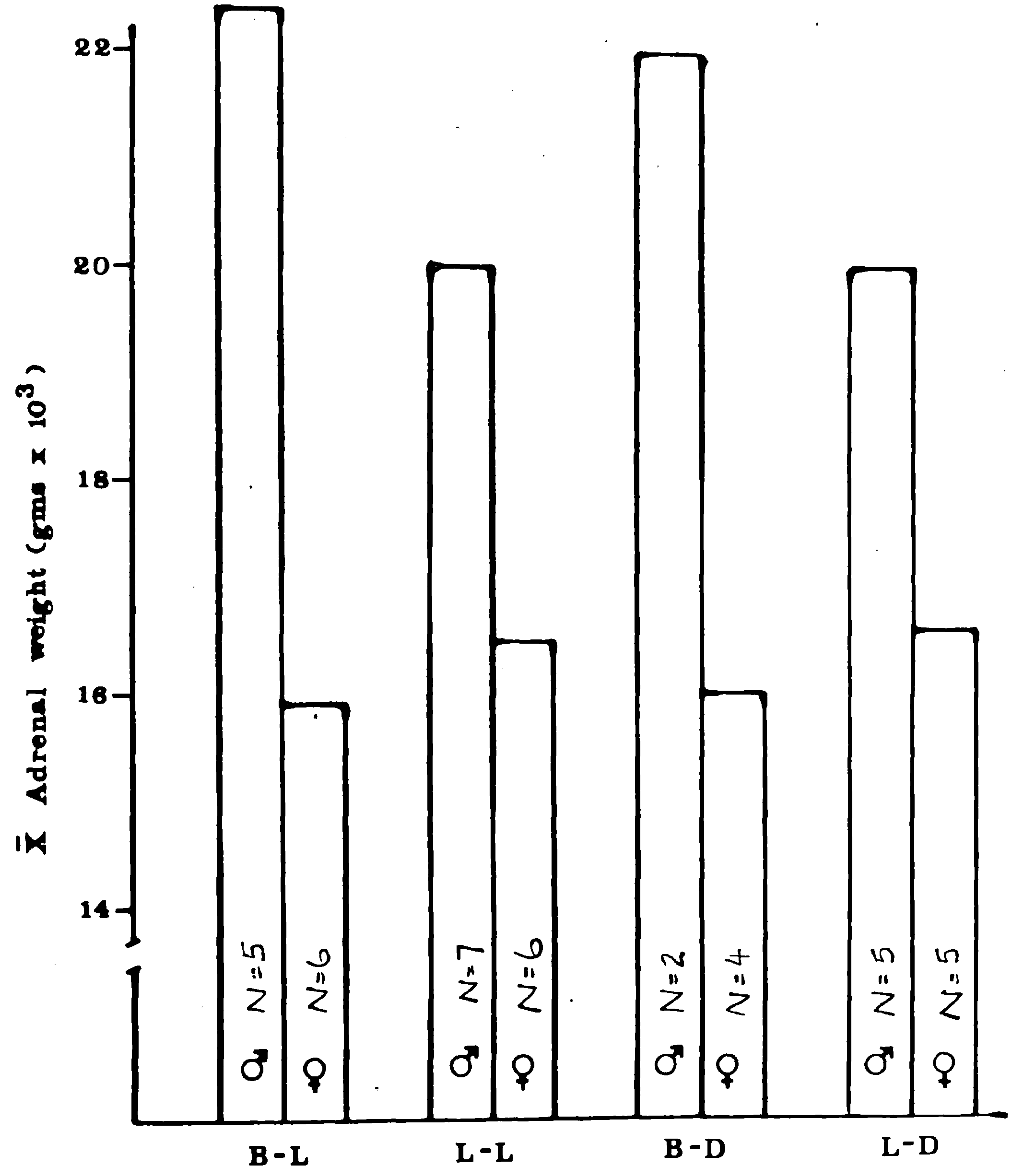
The analysis for adrenal weight (table 31) confirms the expected sex difference in the size of the adrenal glands. Although no other variables attained significance there is an indication that the early burrow condition increases adrenal weight in the male whilst decreasing it in the female - thus exaggerating this normal sex difference. The effect on the males is substantially greater than the effect on the females (see figure 26).

Table 31: Analysis of adrenal weights from males and females reared in different early environments (N = 40)

Source	SS	d.f.	mS	F	p
Preweaning	4.93	1	4.93	<1	
Postweaning	0.04	1	0.04	<1	
Pre x Post	0.00	1	0.00		
Sex	211.51	1	211.51	16.93	<0.001
S x Pre	16.81	1	16.81	1.35	n.s
S x Post	0.35	1	0.35	<1	
S x Pre x Post	0.09	1	0.09	<1	
Error	399.59	32	12.49		
Total	639.90	39			

Figure 26. Adrenal weights of animals reared in different environmental conditions.

Figure 26


X̄ Adrenal weight (gms x 10^3)
22
20
18
16
14
♂ N=5
♀ N=6
♂ N=7
♀ N=6
♂ N=2
♀ N=4
♂ N=5
♀ N=5
B-L
L-L
B-D
L-D

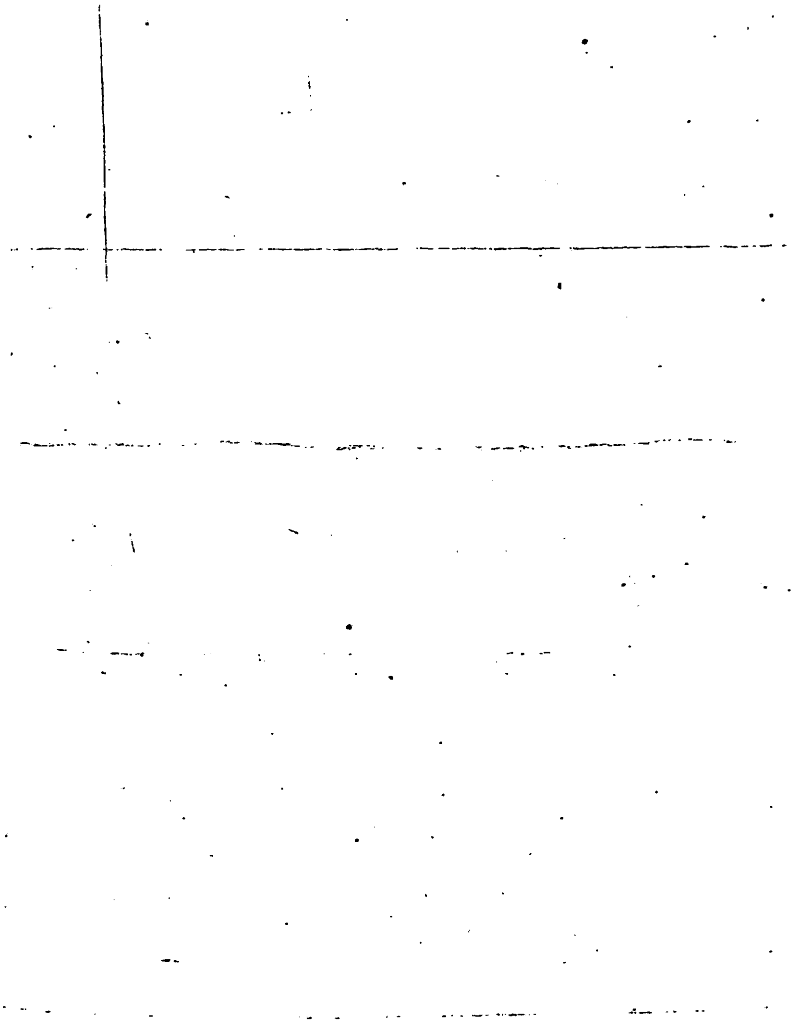
The cortisol levels show no clear sex difference although the value for F is close to the 10% significance level (table 32). The main effect is a decrease in the level of plasma cortisol, in both sexes, due to the postweaning condition. This appears at variance with findings in the rat where it is the preweaning environment that is most effective in producing changes in the pituitary/adrenal axis. These results support the previous finding (Denyes and Horwood, 1960) of a lack of correlation between the size and activity of the adrenal gland in this species. (The difficulty in interpreting these data leads to the realisation that there are only two basic levels of titre obtained (see figure 27) - one group including all the female conditions except the control group with the males in the B-D condition and the second group, with higher levels, all the male conditions except the B-D group with the female control group).

Table 32: Analysis of plasma cortisol levels in males and females from different early environments ($F = 2.87$, df = 1/32, $p = 0.1$).

Source	SS	d.f.	mS	F.	p
Preweaning	23.01	1	23.01	2.62	
Postweaning	47.26	1	47.26	5.39	<0.05
Pre x Post	0.18	1	0.18	<1	
Sex	23.89	1	23.89	2.72	
S x Pre	0.09	1	0.09	<1	
S x Post	2.77	1	2.77	<1	
S x Pre x Post	20.68	1	20.68	2.36	
Error	280.64	32	8.77		
Total	412.97	39			

This finding is not easily explained by either varied basal levels due to early environment, or response levels to stress. That all male animals, except those in the B-D group and females in the control group should give titres indicative of greater stress appears untenable. The difficulty in finding reliable indices and measurement techniques for stress related phenomena has been repeated here.

Figure 27. Plasma cortisol levels of animals reared in different environmental conditions



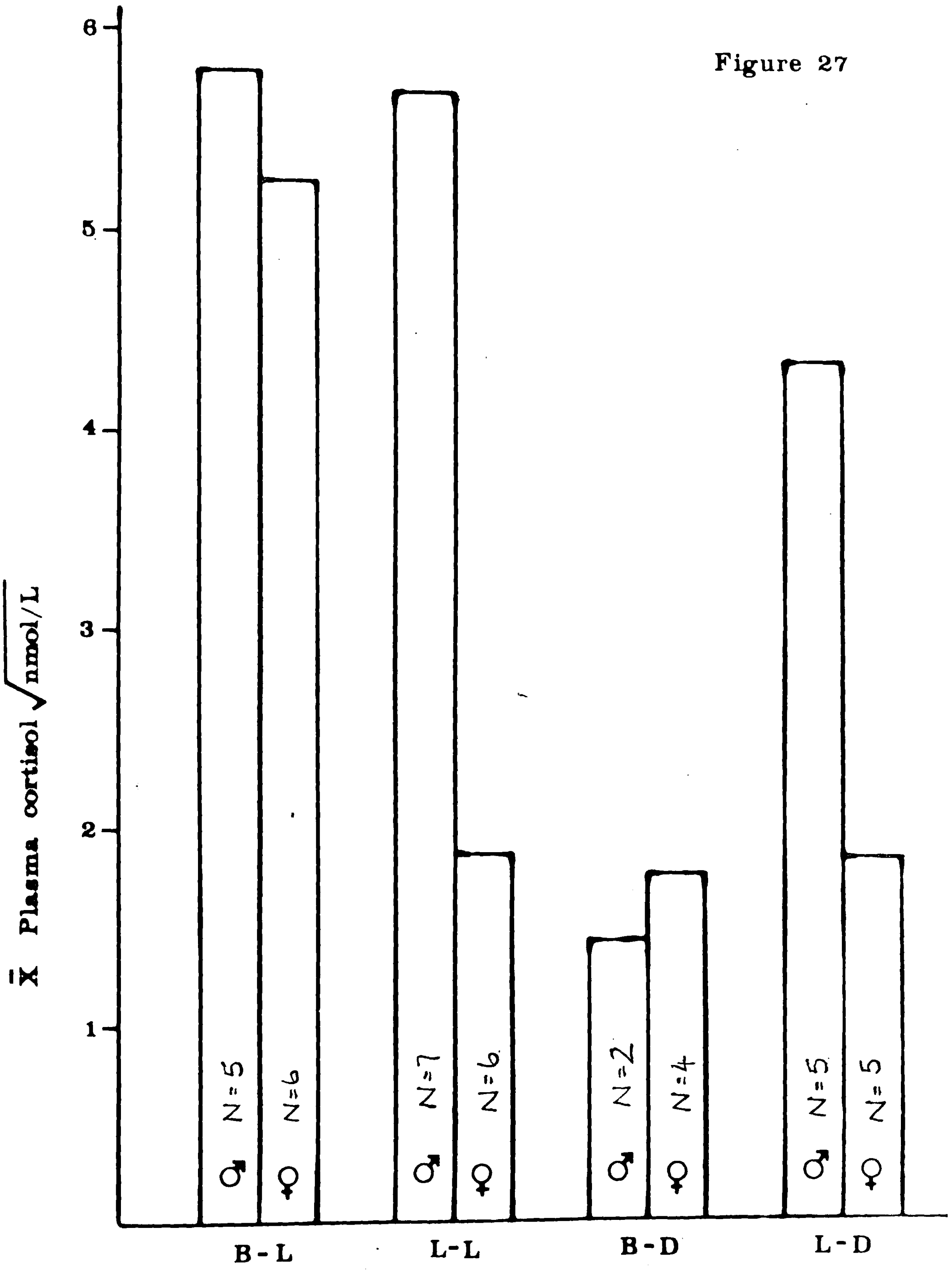


Figure 27

x̄ Plasma cortisol $\sqrt{\text{nmol/L}}$
6
5
4
3
2
1
♂ N=5
♀ N=6
♂ N=7
♀ N=6
♂ N=2
♀ N=4
♂ N=5
♀ N=5
B-L
L-L
B-D
L-D

The females show more real effect from the experimental conditions in these physiological measures than were demonstrated behaviourally. The preweaning condition has little direct effect on either body growth or brain weight, whilst dramatically altering adrenal weight in both sexes. However, there is again no correlation with cortisol levels as these are lowered in the female and unaffected in the male. The postweaning condition serves to increase body weight, particularly in the females, decrease brain weight and cortisol level in the males and not to affect the adrenals. This seems to imply again that the postweaning condition serves to instruct and develop the organism whilst the preweaning environment 'sets' the animals' emotional physiology for appropriate situation response.

Discussion and Conclusion

A general assessment of the results verifies the supposition that a quiet, early (more 'natural') environment does allow the development of a more adaptive organism reflected in low ambulation in novel situations together with faster reactivity to novelty and rapid learning. This appears to be achieved by the setting of the animals' emotional responses or arousal level physiologically in early life. An enriched postweaning environment has similar overall effects achieved not by a physiological parameter but by an experiential one.

The main interest in this study arises from the interaction of the two environments which does not appear as beneficial as proposed. This can be accounted for by the great contrast between the two conditions of burrow and desert which the organism would naturally have greater control over, and so be able to adapt gradually to the different experiences. It was felt in this research that the change in environment, was too sudden for the real benefit to be demonstrated. An improved design for the conditions may provide more information in this respect. Effects, unexplained by either the burrow or the desert directly, may largely be explained by this proposal.

In summary, the main proposition has been verified demonstrating a more natural environment, at least in this species, does provide a more responsive, adaptive animal bearing in mind the caution re the interactive consequences. The fact that interaction has been demonstrated repeatedly here serves to illustrate the care that must be taken in assessing an animals' total experience throughout development and maturity before interpreting results.

SECTION 3: THE EFFECTS OF HANDLING IN THE HAMSTER

SECTION 3: THE EFFECTS OF HANDLING IN THE HAMSTER

The experimental data detailed in this section were obtained in order to test a specific hypothesis; namely that "handling days 0-21 in the hamster produces deleterious effects by affecting physiological brain differentiation and development during a critical period of early life". The formulation of this hypothesis has been discussed in full elsewhere (see Chapter III - The Golden Hamster). Such a general hypothesis, together with the argument put forward in its conception, leads on to a number of other statements which will be critically assessed.

(i) Handling in the hamster days 0-21 will be expected to produce deleterious effects dissimilar, and generally in the reverse direction, from those effects (commonly termed 'beneficial') produced by handling days 0-21 in the laboratory rat.

(ii) Handling in the hamster days 5-21 will be expected to produce effects commonly associated with handling in the laboratory rat.

(iii) Handling in the hamster days 0-4 will be found to result in deleterious effects, as expected in handling days 0-21; and that this period (days 0-4) may be a critical period in producing the effects of handling days 0-21.

(iv) The non-handled (NH) group will be a second control group, no different from the first control group.

The approach in this section is of necessity different from the previous sections in that a highly specific experimental hypothesis has been formulated. This is possible as there is some evidence available in this field (i.e. handling in hamsters) already, allowing previous experimental results and background information to be critically assessed and combined (see pp.74-79), so that a very precise testable hypothesis (or series of hypotheses) can be derived.

Apart from the experimental procedure these animals were treated in an identical manner to all other groups as already described, undergoing the same behavioural and physiological assessments. Results for all groups were analysed by an analysis of variance (which included all groups) using litter means as the unit of analysis. The data were also subjected to analysis with the q-statistic in an effort to determine which groups were like, and which unlike, each other. (Harmonic means were used when groups were of unequal size). Behavioural observations are detailed in appendix A.

Growth

Using a repeated measures analysis of variance for mean litter body weight at weaning, 55 days and 90 days, a significant trials effect was found for both sexes and a significant effect of condition in the males only (Table 33). The sample taken at maturity for physiological measures gave a highly significant effect for both sex and condition (Table 34) - although again there is some difference between the values obtained from the sample and those obtained using litter means in this case it only affects the strength of the significance. The growth curves reflect the result of the first analysis by showing that the control group has the best growth, whilst all forms of handling appear to depress body weight (see figure 28).

This is true of the females as well as the males, despite the lack of significance. The NH and the H_{5-21} groups have similar curves with the H_{0-21} group showing the poorest growth. The H_{0-4} group have very low weaning weights which recover before maturity to exceed the weights achieved in the H_{0-21} group. This tendency to catch up on growth during maturity is shown by all the experimental conditions with NH animals doing best to show increased weight at maturity and the H_{0-21} doing least well; H_{5-21} do slightly better than H_{0-4} (see figure 29).

Table 33a: Repeated analysis of variance for body weights of males in the handling conditions (3 litters/condition).

Source	SS	d.f.	mS	F	p
Conditions	1529.86	4	382.47	2.95	<0.1
error	1167.11	9	129.68		
Total subjects	2696.97	13			
Trials	40083.24	2	20041.62	706.19	≤ 0.001
T x C	334.54	8	41.82	1.47	n.s
error	510.89	18	28.38		
Total Variance	43625.64	41			

Table 33b: Repeated analysis of variance for body weights of females in the handling conditions (3 litters/condition)

Source	SS	d.f.	mS	F	p
Conditions	1497.91	4	374.48	1.54	n.s
error	1940.89	8	242.61		
Total subjects	3438.80	12			
Trials	49756.13	2	24878.07	373.26	≤ 0.001
T x C	360.09	8	45.01	<1	
error	1199.78	18	66.65		
Total Variance	54754.80	40			

Table 34: Analysis of variance for mature animals (90+ days) with early handling experiences (sample only) (N = 68♀; 58♂).

Source	SS	d.f.	mS	F	p
Conditions	11227.44	4	2806.86	18.19	<0.001
Sex	1913.87	1	1913.87	12.4	$=0.001$
S x C	298.98	4	74.75	<1	
error	7254.15	47	154.34		
Total Variance	23463.93	56			

Figure 28. Growth curves of litters reared in the handling conditions: (a) males
(b) females

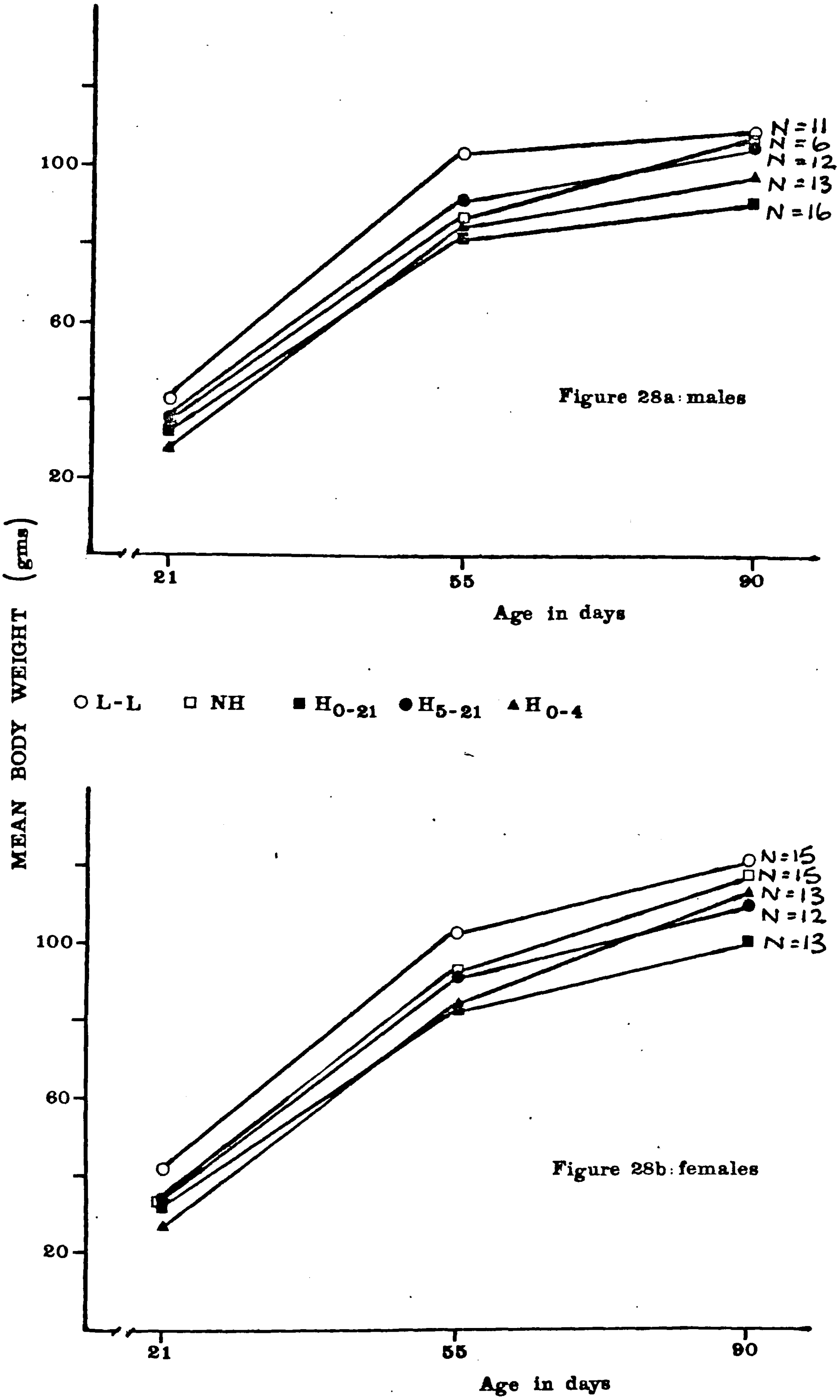


Figure 28a: males

Figure 28b: females

The pattern that emerges from the mature weights is very interesting - in the males: groups H_{5-21} and H_{0-4} are both similar to the control group, NH group has increased body weight and the H_{0-21} group has a depressed body weight; in the females: a similar pattern is repeated with groups H_{5-21} and H_{0-4} also having slightly elevated body weight. This finding emphasises the permanent consequence of experimental manipulation which must obviously be having some effect throughout the animal's lifespan, as does the result from the analysis (table 34).

The findings are verified by the q-statistic which groups the controls (although overall distinct from the other groups) with the NH and H_{5-21} and groups H_{0-21} and H_{0-4} together. As well as having poor growth those animals which had received handling early in life were also of very poor appearance generally. Overall, these results bear out the hypothesis suggested well, supporting the theory that there is some fundamental impairment in this species as a result of early handling.

Open-field behaviour

This was measured using standard O/F technique (see p.125) scoring ambulation as sections entered and rearing. Results were analysed using litter means with 3 litters/condition. Ambulation in the males is noticeably depressed by handling days 0-21 - both the control and the H_{0-21} groups being significantly different from each other and all other conditions. The analysis gives a significant conditions effect as well (table 35a). In the other groups: NH mirrors the control response to the open-field with slightly depressed scores whilst both H_{0-4} and H_{5-21} have similar, unusually shaped curves. The females analysis gives no significant result other than a trials effect as would be expected, with all groups ambulating more than the males (table 35b).

Figure 29. Body weights of mature (90+ days) animals from handling conditions.

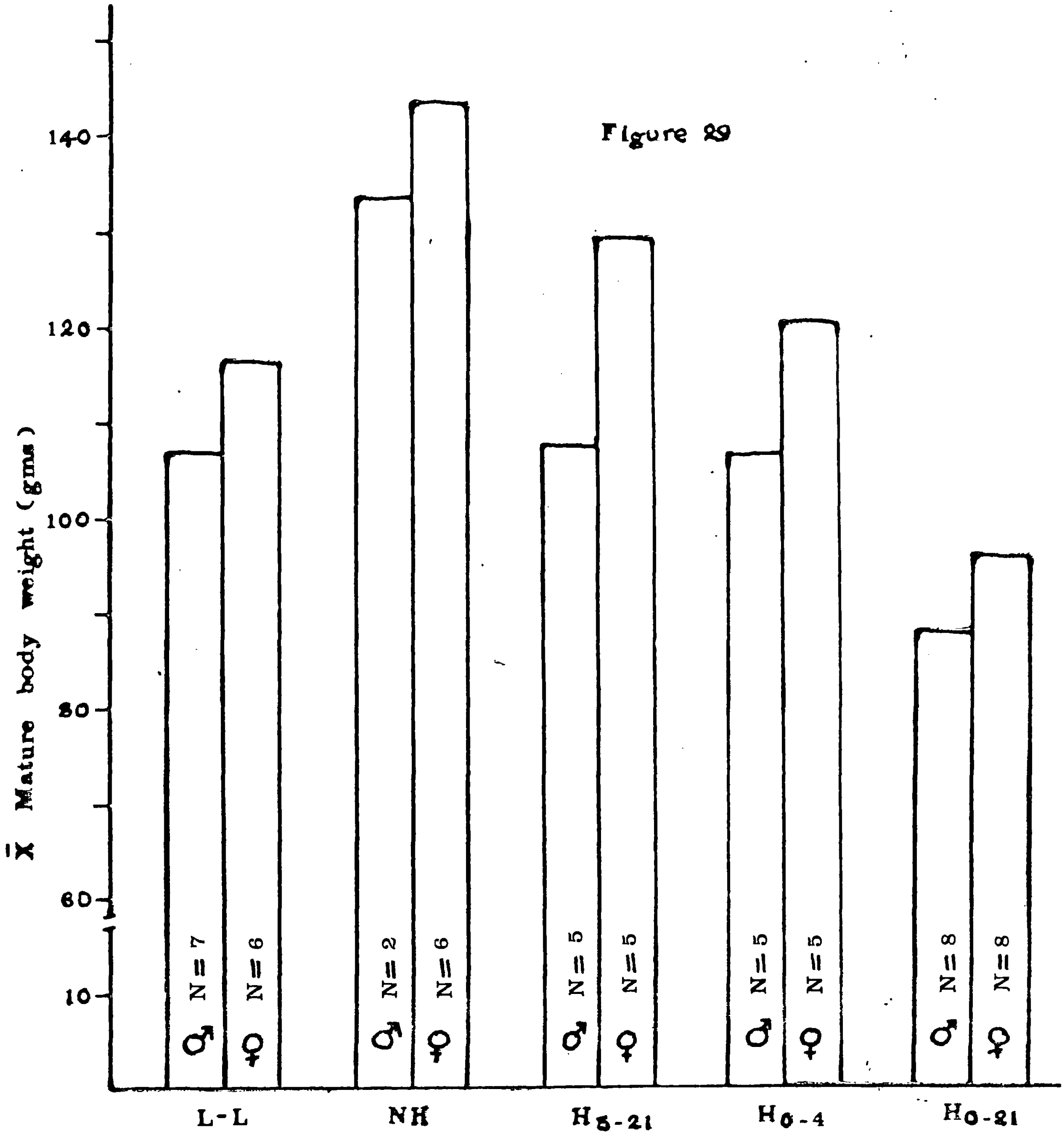


Figure 29
X̄ Mature body weight (gms)
140
120
100
80
60
10
♂ N = 7
♀ N = 6
♂ N = 2
♀ N = 6
♂ N = 5
♀ N = 5
♂ N = 5
♀ N = 5
♂ N = 8
♀ N = 8
L-L
NH
H5-21
H0-4
H0-21

Table 35a: Repeated analysis of variance for open-field ambulation in males from the handling conditions (N=58)

Source	SS	d.f.	mS	F	p.
Condition	1695.4	4	423.85	2.67	<0.1
error	1367.0	9	151.89		
Total subjects	3062.4	13			
Trials	1654.05	3	551.35	11.93	<0.001
T x C	582.2	12	48.52	1.05	n.s
error	1248.0	27	46.22		
Total Variance	6546.65	55			

Table 35b: Repeated analysis of variance for open-field ambulation in females from the handling conditions (N=68)

Source	SS	d.f.	mS	F	p.
Conditions	1156.83	4	289.21	<1	
error	3542.50	8	442.81		
Total subjects	4699.33	12			
Trials	3395.80	3	1131.93	28.96	≤0.001
T x C	703.03	12	58.59	1.50	n.s
error	938.17	24	39.09		
Total Variance	9736.33	51			

In the females the tendency is for the groups NH and H_{5-21} to show a similar response to the control group, whilst H_{0-4} and H_{0-21} have similar flattened curves indicating somewhat increased emotionality (day 1) followed by increased exploration (days 3 and 4) - see figure 30. This effect is similar to that found by Lawlor et al (1975) using mean litter scores but does not verify the finding of generally increased open-field ambulation as shown by Swanson (1969).

Rearing scores also give a significant conditions effect for the males and not the females (table 36). In this case rearing is depressed in groups NH and H_{5-21} in both sexes, particularly the males, and also H_{0-21} in the males. In the females the three groups H_{0-4}, H_{0-21} and control are very similar in response (see figure 31). Animals that have been handled wash less in the open-field especially the females, and the males, are less likely to cross the centre of the field particularly during the first day of testing. Although some of these animals that have been handled may attain fairly high open-field scores their manner in doing so is not an easy relaxed attitude as, for example, shown by some of the animals from the previous experiment, but an extremely nervous, frantic behaviour. (The ambulation scores obtained from the novelty test give little information in this case other than the over-riding sex difference, which is apparent from examination of the figure for open-field ambulation).

These results may be summed up briefly as demonstrating a reduction in ambulation and exploration in males handled days 0-21, due to an increased emotionality although this effect is not obviously occurring in the females. The other groups which have undergone various degrees of handling show these effects to a lesser or greater extent. The overall picture is difficult to assess as none of the conditions show any consistent tendency to group in the manner suggested in the formulation of the experimental hypothesis.

Figure 30. Open-field ambulation of litters from handling conditions: total sections entered (a) males (b) females

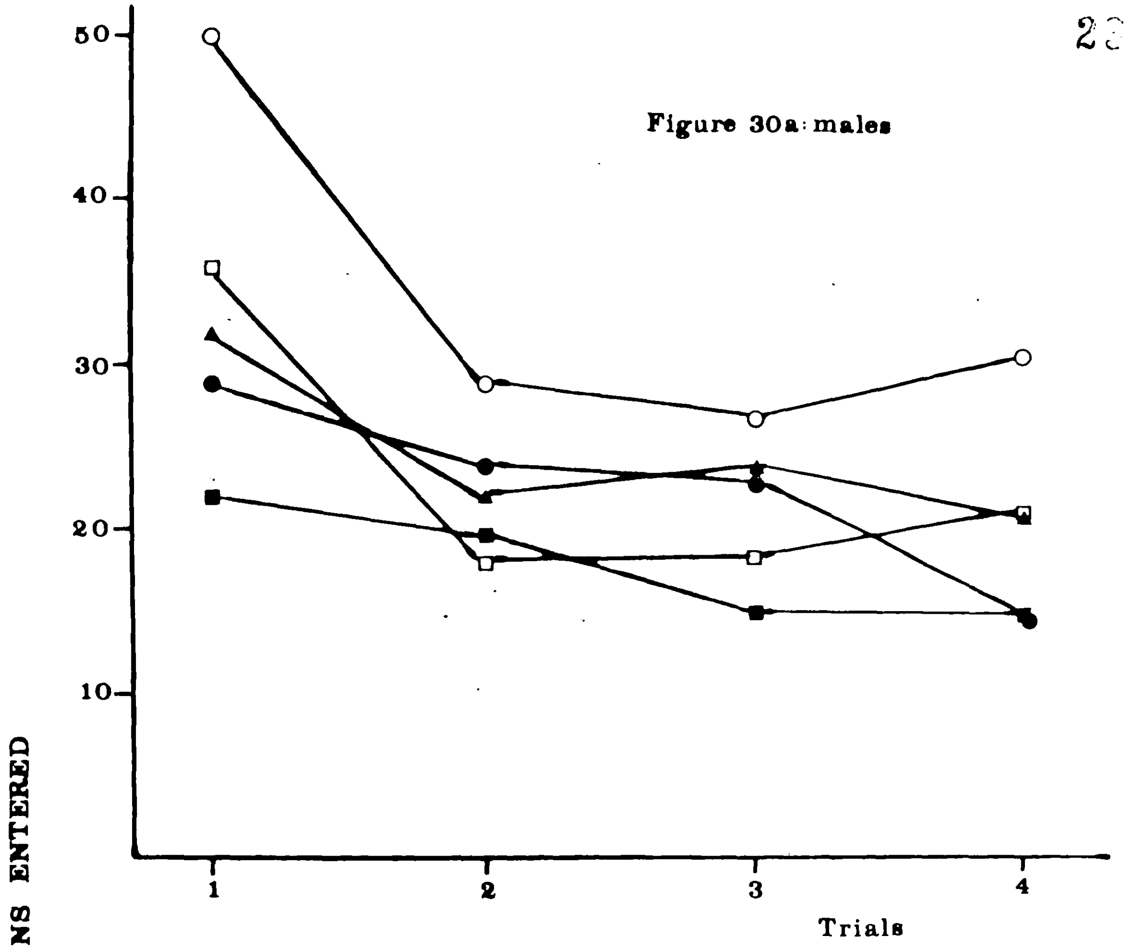


Figure 30a: males

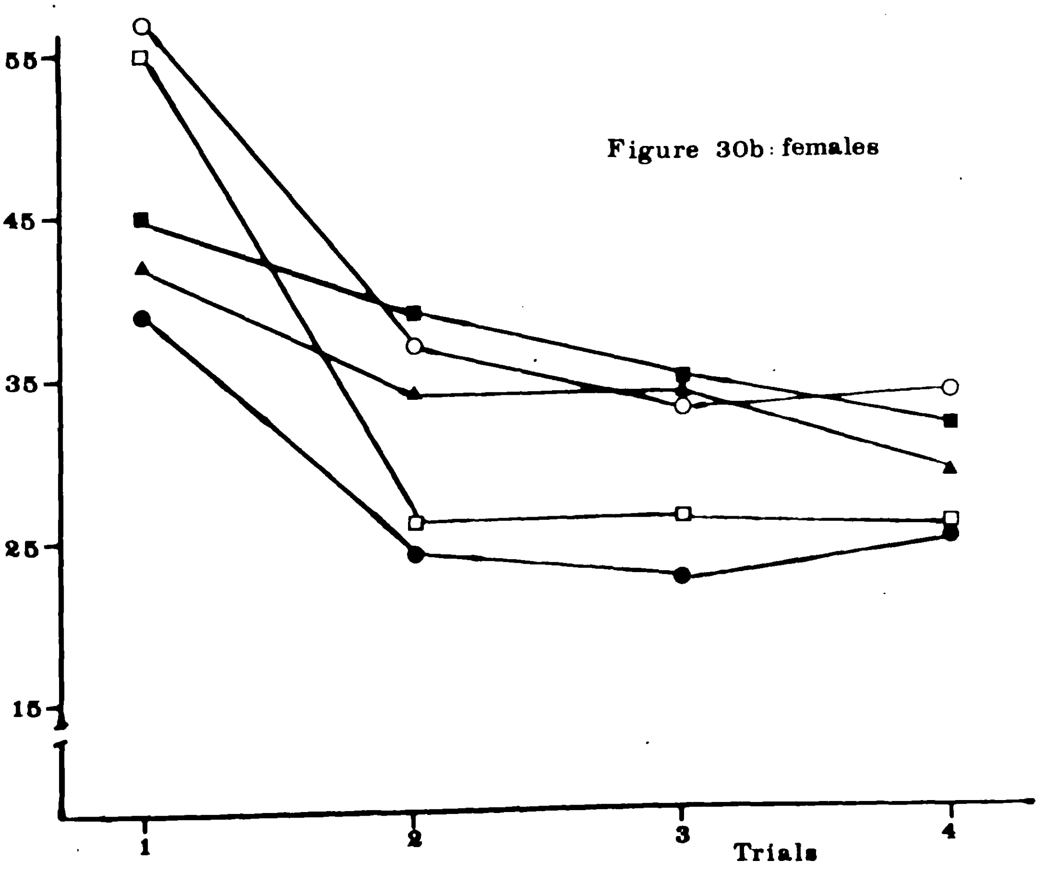


Figure 30b: females

Table 36a: Repeated analysis of variance for open-field rearing in males from the handling conditions (N = 58).

Source	SS	d.f.	mS	F	p.
Conditions	1099.10	4	274.78	4.12	<0.05
error	600.83	9	66.76		
Total subjects	1699.93	13			
Trials	80.73	3	26.91	3.84	<0.05
T x C	36.10	12	3.01	<1	
error	189.17	27	7.01		
Total Variance	2005.93	55			

Table 36b: Repeated analysis of variance for open-field rearing in females from the handling conditions (N = 68).

Source	SS	d.f.	mS	F	p.
Conditions	374.43	4	93.61	<1	
error	2001.50	8	250.19		
Total subjects	2375.93	12			
Trials	292.58	3	97.53	10.3	<0.001
T x C	50.5	12	4.21	<1	
error	227.17	24	9.47		
Total Variance	2946.18	51			

Figure 31. Open-field rearing of litters from handling conditions:

(a) males

(b) females

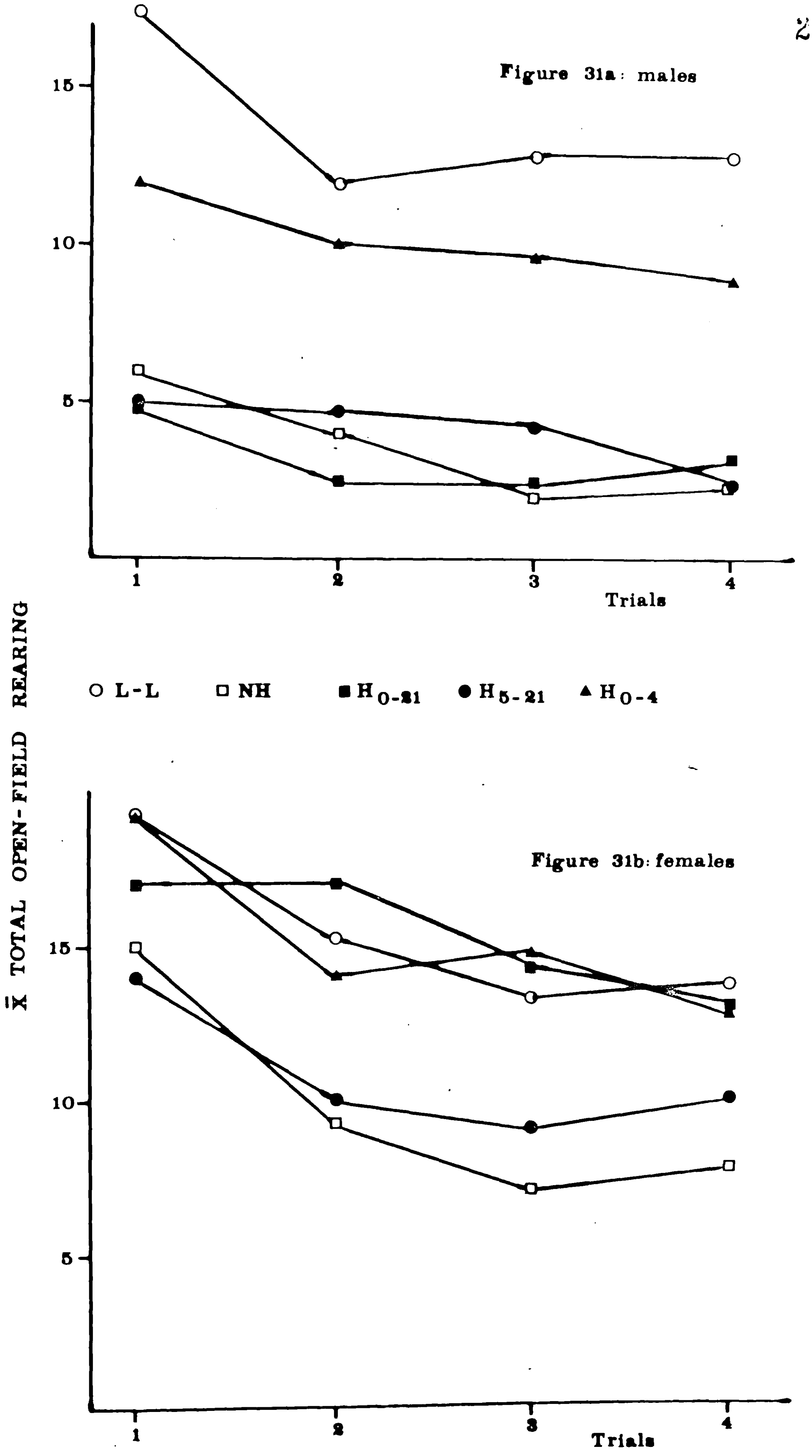


Figure 31a: males

Figure 31b: females

Novelty Testing

All 3 litters from each condition were tested in the novelty box (see p.126 for procedure) and their mean scores used in analysis. Scores were recorded for latency to respond to novel objects (referred to here as R/T) and total time spent on objects (T/O).

Although neither of the analyses for latencies to response in this test give significant effects other than for trials (males: $F = 5.38$, d.f. = 1/9, $p < 0.05$; Females: $F = 22.85$, d.f. = 1/8, $p < 0.01$), the results provide an interesting graphical display (see figure 32).

In the males the normal response of longer latencies to response to the second object than the first is shown, with NH and control groups both giving classical data. Handling days 0-4 appears to decrease reactivity to the second object whilst handling days 5-21 increases it. The group that stands out is the H_{0-21} who show very slow initial latencies to response. In the females all groups give the standard, control response except H_{0-4} who again show decreased reactivity to the second object.

Surprisingly the analysis for the males' time on object gave significant results for both condition and trial x conditions; the female analysis gave no significant results at all - despite the fact one might expect an effect of trial (see table 37). Although what has happened is not very clear, and although there is no relation between the animals R/T and T/O it seems that the more early, extreme handling a male animal receives the more neophobic he is, although 'milder', possibly less damaging, forms of stimulation (i.e. groups NH and H_{5-21}) increase exploration once initial emotionality has been overcome. In the females, too, this initial low level of exploration of a novel object is apparent (figure 33).

Figure 32. Latency to respond to objects in novelty test of litters from the handling conditions:

(a) males

(b) females

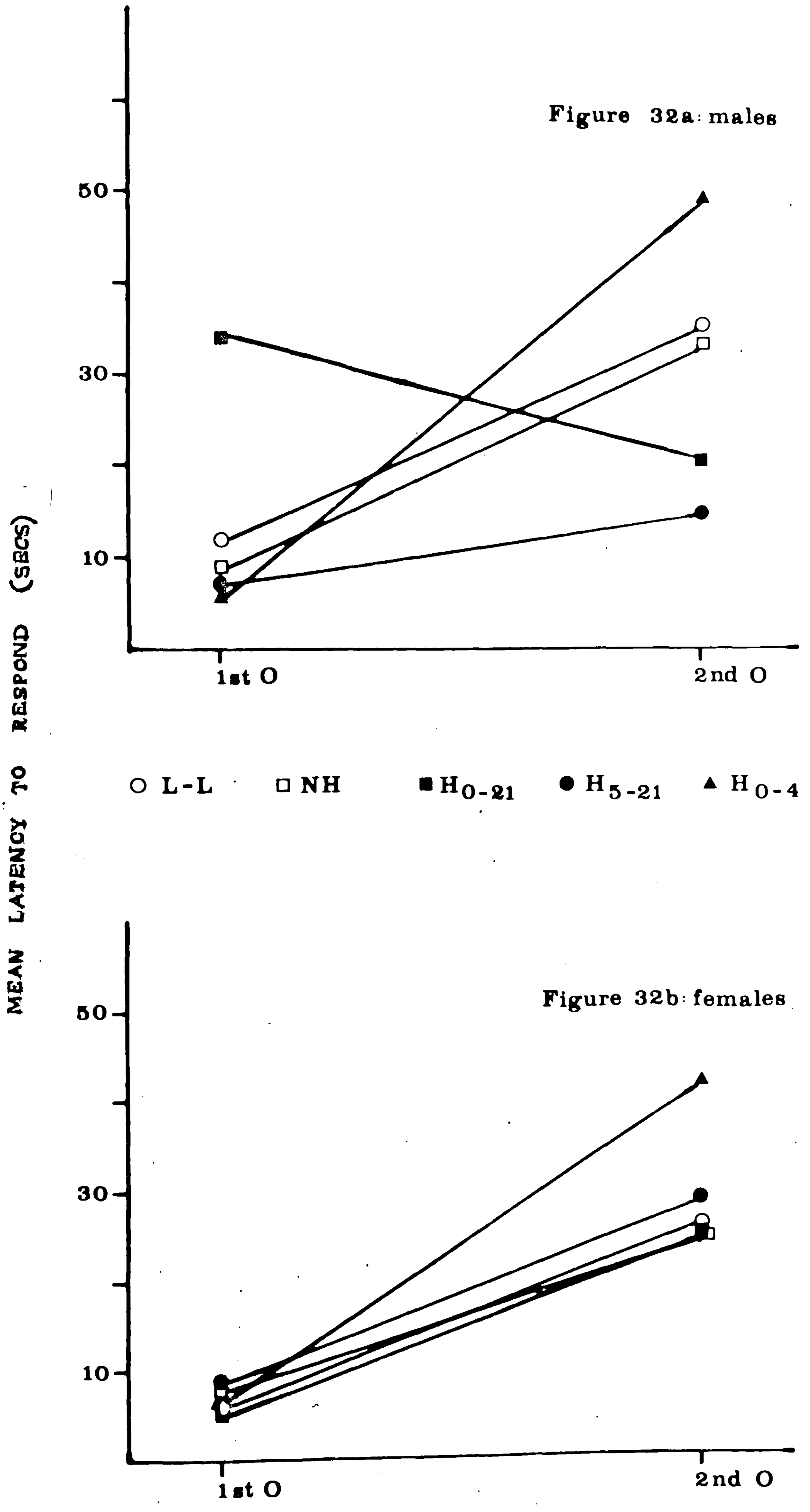


Figure 32a: males

Figure 32b: females

Table 37a: Repeated analysis of variance for time on objects in novelty test of males from handling conditions(N = 58).

Source	SS	d.f.	mS	F	p.
Conditions	928.14	4	232.04	3.2	<0.05
error	652.33	9	72.48		
Total subjects	1580.47	13			
Trials	8.54	1	8.54	<1	
T x C	421.46	4	105.37	4.29	<0.01
error	221.00	9	24.56		
Total Variance	2231.47	27			

Table 37b: Repeated analysis of variance for time on objects in novelty test of females from handling conditions(N = 68).

Source	SS	d.f.	mS	F	p.
Conditions	636.14	4	159.04	1.86	n.s
error	685.33	8	85.67		
Total subjects	1321.47	12			
Trials	64.54	1	64.54	2.31	n.s
T x C	105.46	4	26.37	<1	
error	224.00	8	−28.00		
Total Variance	1715.47	25			

Figure 33. Total time spent on objects in novelty test of litters from the handling conditions: (a) males
(b) females

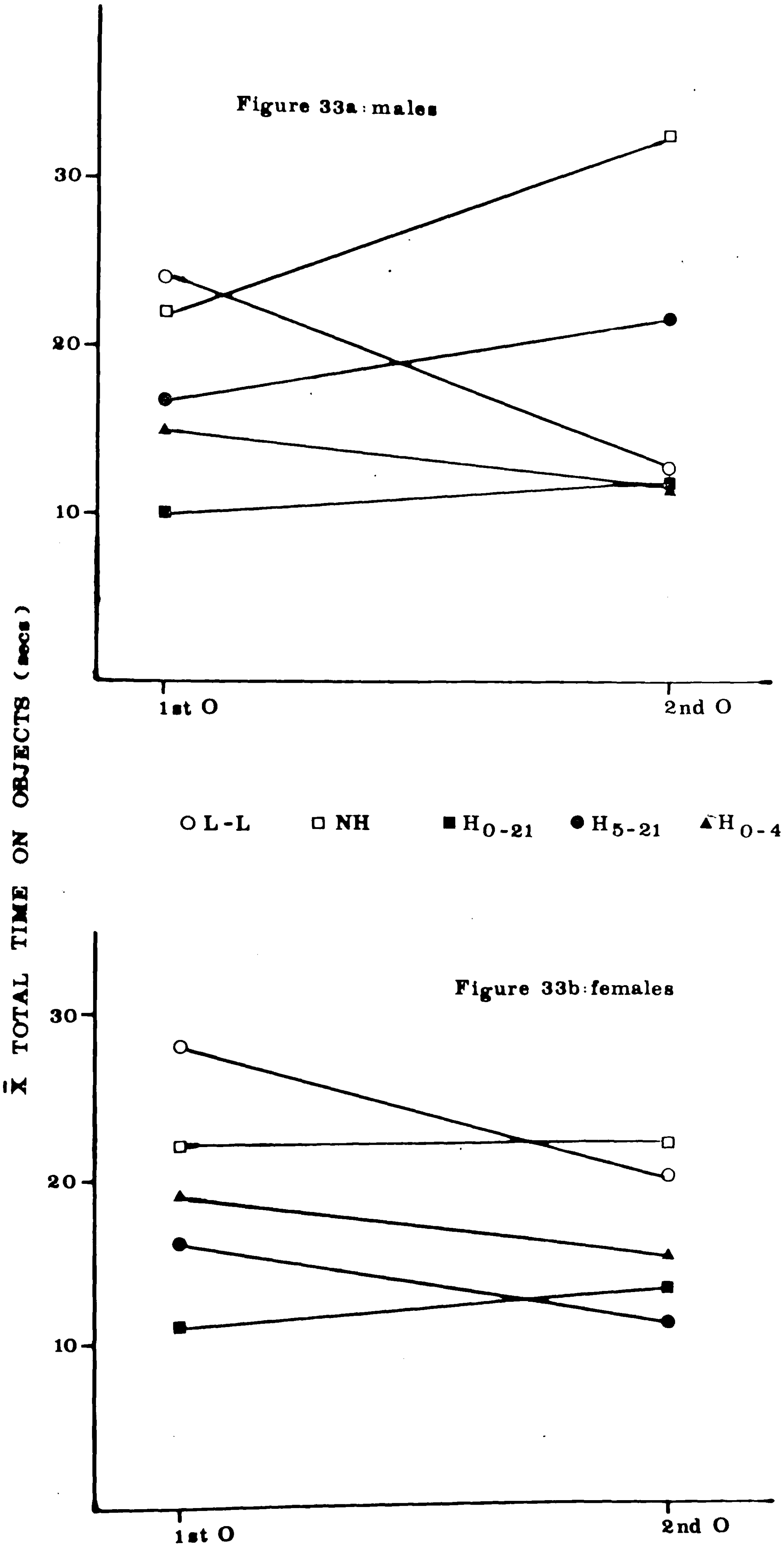


Figure 33a: males
30
20
10
1st O
2nd O
X̄ TOTAL TIME ON OBJECTS (secs)
○ L-L
□ NH
■ H0-21
● H5-21
▲ H0-4
Figure 33b: females
30
20
10
1st O
2nd O

Discrimination Learning *

The test showed that all groups were quite capable of learning a simple discrimination although none of these experimental groups reached the ceiling for learning (i.e. 60 correct responses). Indeed groups H_{0-4} and H_{0-21} did worse on day 4 than day 3 - illustrating their erratic approach to the test situation (figure 34). All effects were significant in the analysis of variance with, by far, the major source of variance, coming from the trials effect (table 38). No significant results could be obtained from the time taken by the subjects to acquire learning although handling tends to increase the speed of the runs. Probably a measure of the total number of errors made would have illustrated the different approach of these groups to the acquisition of learning - often handled animals, particularly H_{0-21} and H_{5-21}, did not seem to understand or recall the task at all. Again, as in the open-field, although the various groups may attain similar scores, the style in which they are attained is very different - observation of behaviour rather than mere scoring in these test situations could well have been more enlightening, particularly when behavioural patterns might be correlated into more meaningful indices of behaviour.

Table 38: Repeated analysis of variance for correct number of responses made in discrimination learning by males from the handled conditions ($N = 15$).
(*F = 3.71, d.f. = 4/10, p = 0.05).

Source	SS	d.f.	mS	F	p.
Conditions	47.90	4	11.98	3.54	<0.1*
error	33.83	10	3.38		
Total subjects	81.73	14			
Trials	792.18	3	264.06	94.99	<0.001
T x C	69.57	12	5.80	2.09	=0.05
error	83.50	30	2.78		
Total Variance	1026.98	59			

---

* -3 males from each condition were used in this test, following the procedure described in detail on p.129, for a simple black/white discrimination in the SMVDA.

Figure 34. Discrimination learning curves of males from the handling conditions: total number of correct responses.

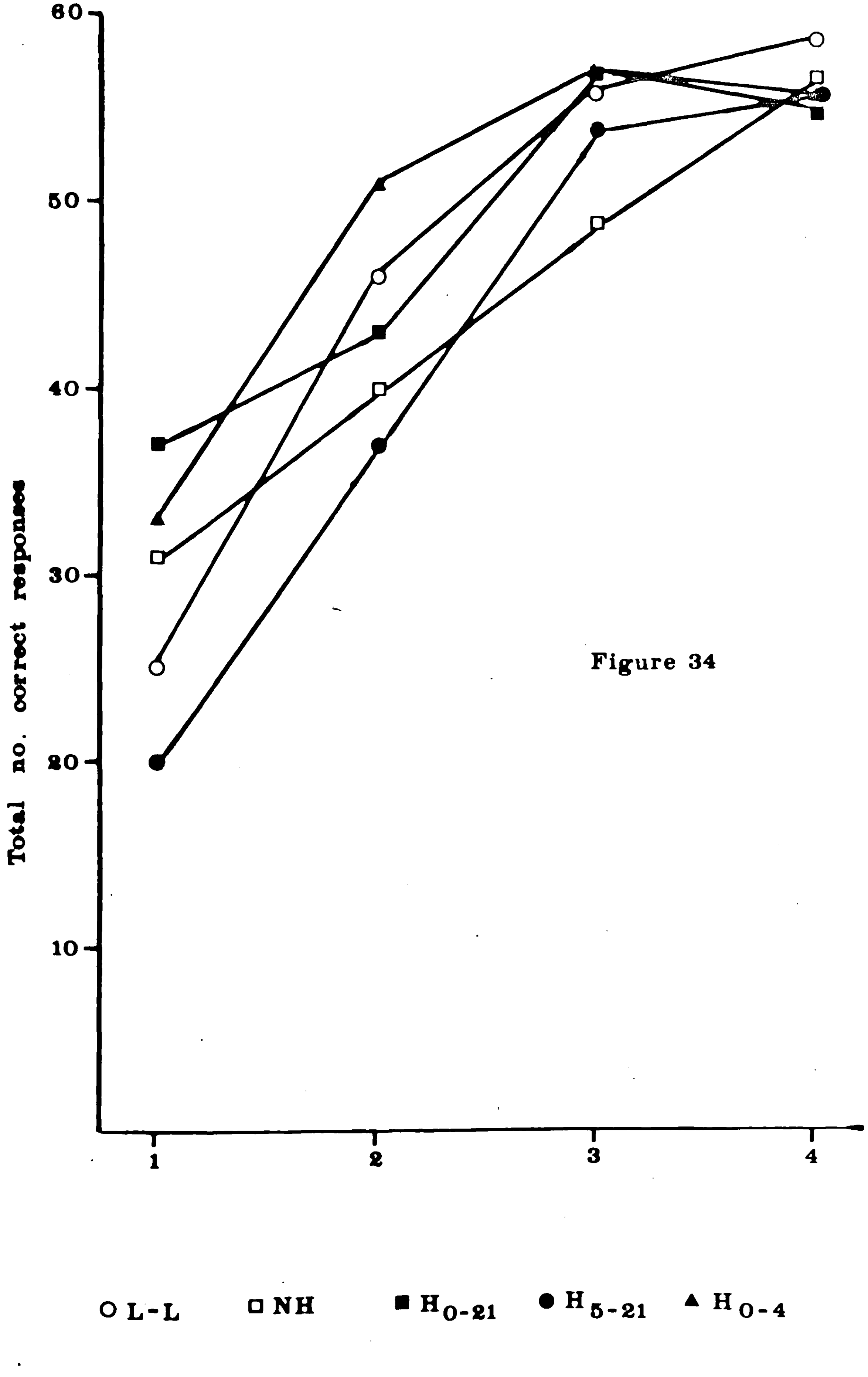

60
50
40
30
20
10
Total no. correct responses
1
2
3
4
○ L-L
□ NH
■ H_{0-21}
● H_{5-21}
▲ H_{0-4}

Figure 34

Physiological Measures

(i) Brain Weight

Significant effects are found here for condition and sex x condition (table 39a), mainly explained by the decrease in brain weight in males H_{0-21}. The other handling conditions in the male are similar to the control group, although handling in the female tends to depress brain weight with a slight increase in the non-handled group (see figure 35a). Again, there seems no relation with body weight and little correlation in the males with cognitive performance, as found in the previous sections (see table 39b and figure 35b).

Table 39a: Analysis of variance for brain weight of mature animals from handling conditions (sample only). (N = 30 F; 27 M).

Source	SS	d.f.	mS	F	p
Conditions	178.15	4	44.54	2.34	< 0.1
Sex	8.70	1	8.70	< 1	
S x C	177.34	4	44.34	2.33	< 0.1
error	858.29	45	19.07		
Total Variance	1328.11	54			

Table 39b: Analysis of variance for brain/body weight ratios of mature animals from handling conditions (sample only).

Source	ss	d.f.	mS	F	p
Conditions	2823.64	4	705.91	11.53	<0.001
Sex	471.21	1	471.21	7.696	<0.01
S x C	318.13	4	79.53	1.299	n.s.
error	2755.54	45	61.23		
Total	6818.55	54			

Figure 35a: Brain weights of animals from the handling conditions.

Figure 35b: Brain/body weight ratios of animals from the handling conditions.

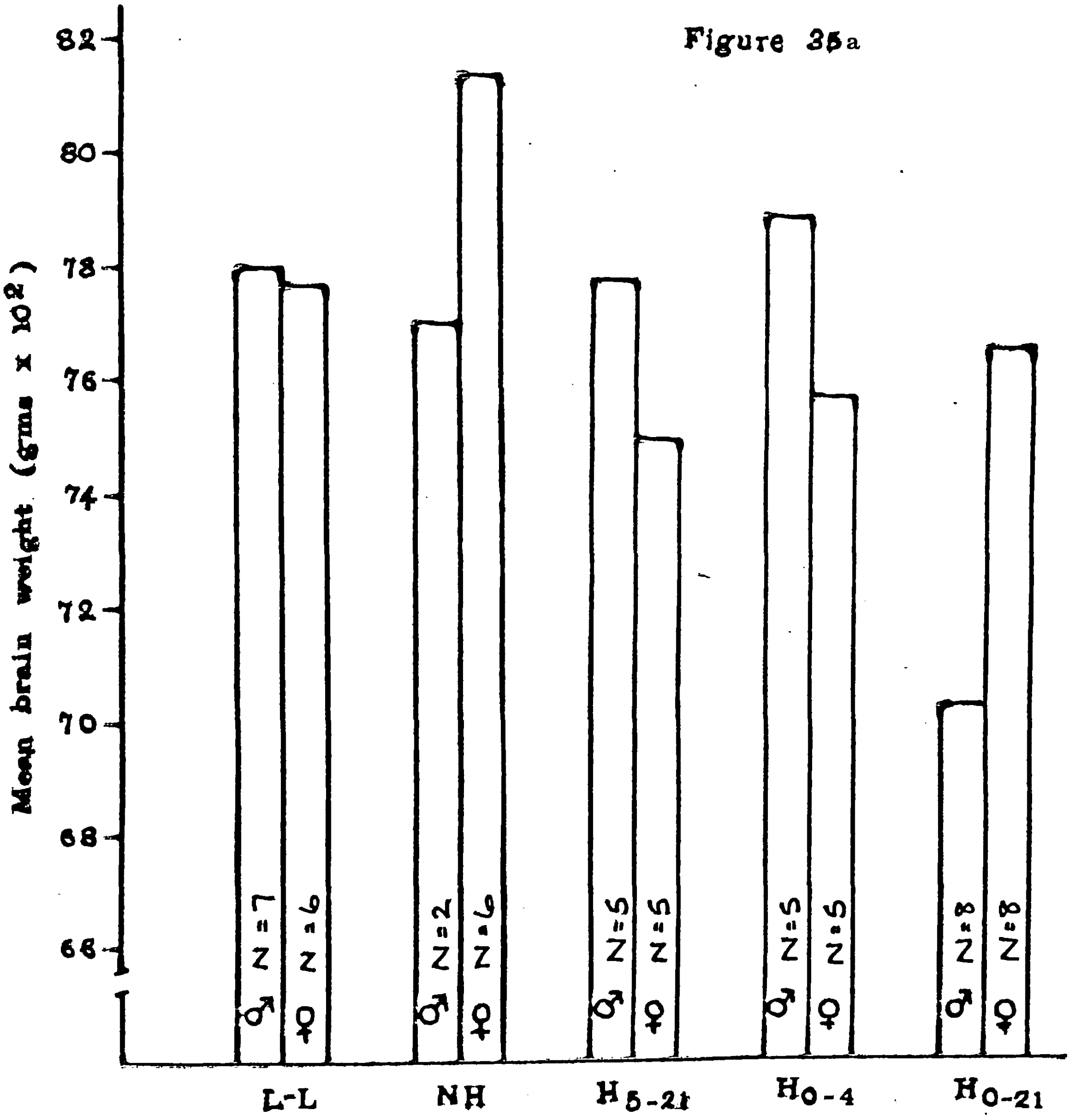
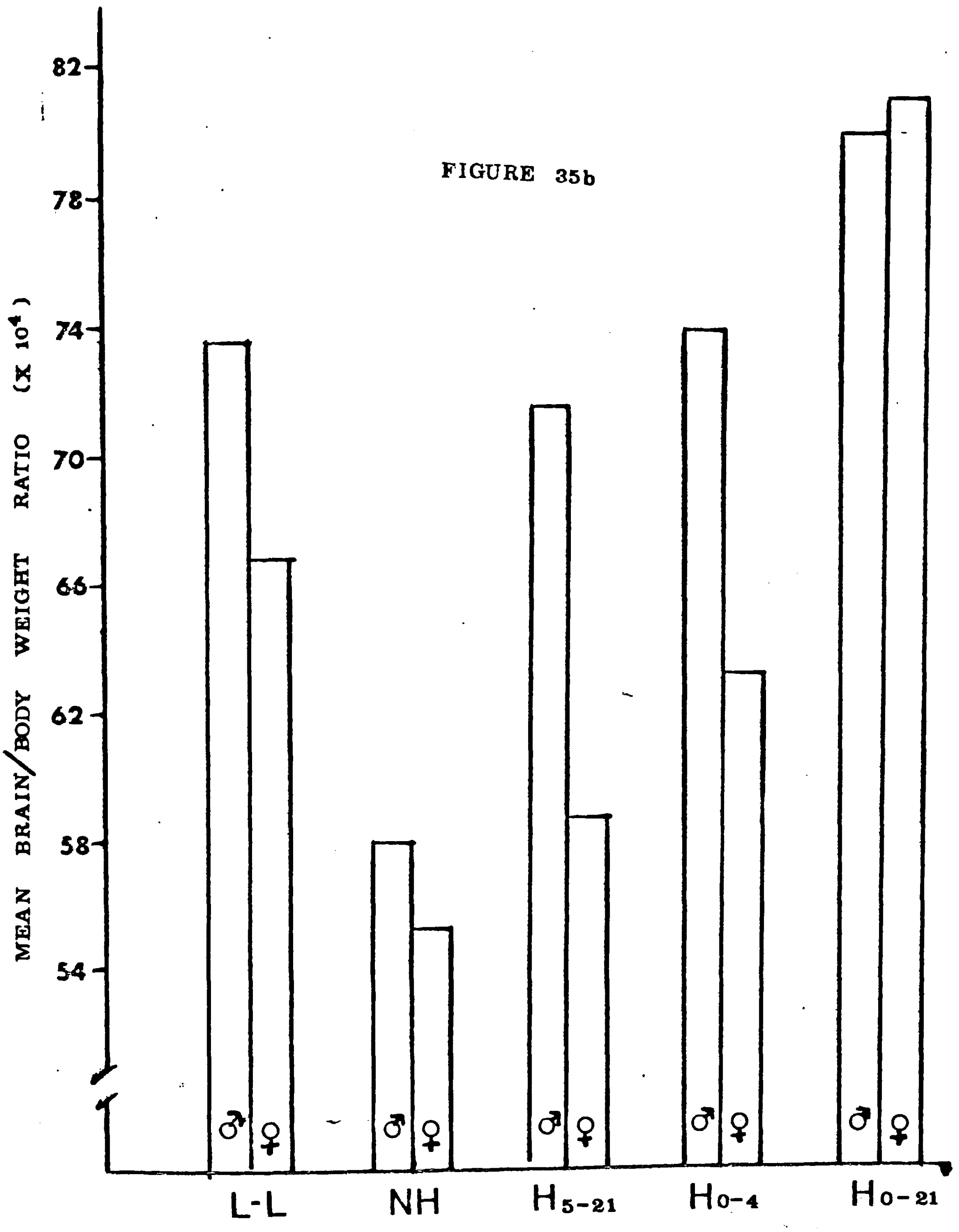


Figure 35a

Mean brain weight (gms x 10^2)
82
80
78
76
74
72
70
68
66
♂ N=7
♀ N=6
♂ N=2
♀ N=6
♂ N=5
♀ N=5
♂ N=5
♀ N=5
♂ N=8
♀ N=8
L-L
NH
H_{5-21}
H_{0-4}
H_{0-21}

FIGURE 35b


MEAN BRAIN/BODY WEIGHT RATIO ($\times 10^4$)
82
78
74
70
66
62
58
54
♂
♀
L-L
NH
H_{5-21}
H_{0-4}
H_{0-21}

(ii) Adrenal weight and plasma cortisol levels

In both these analyses (table 40 and 41) very significant effects due to sex were found, with female values being lower than those of the males in all cases (see figures 36 and 37). Adrenal weight is also significantly affected by condition, with H_{0-21} leading to depressed values in both sexes, although NH elevates the adrenal weight in the males.

The cortisol levels show a significant interaction of sex x condition which is explained by the fact that all experimental conditions cause elevation of plasma cortisol in the males whilst depressing it in the females (see figure 37) - the most dramatic effects being obtained in animals from the conditions H_{0-4} and H_{5-21}.

This reverse response appears to be a reflection of the different stress reaction.

The size of the adrenal gland again appears unrelated to the level of circulating cortisol (an indicator of activity in many species) as found by Denyes and Horwood (1960).

Table 40: Analysis of variance for adrenal weights of mature animals (90+ days) from handling conditions (sample only), (N=30♀; 27♂).

Source	SS	d.f.	mS	F	p.
Conditions	109.00	4	27.25	2.74	<0.05
Sex	302.74	1	302.74	30.49	≤0.001
S x C	33.12	4	8.28	<1	
error	466.66	47	9.93		
Total variance	926.32	56			

Table 41: Analysis of variance for plasma cortisol levels of mature animals from handling conditions (sample only), (N=30♀; 27♂).

Source	SS	d.f.	mS	F	p.
Conditions	9.48	4	2.37	<1	
Sex	188.03	1	188.03	30.38	≤0.001
S x C	65.76	4	16.44	2.66	<0.05
error	284.63	46	6.19		
Total Variance	661.84	55			

Figure 36. Adrenal weights of animals from the handling conditions.

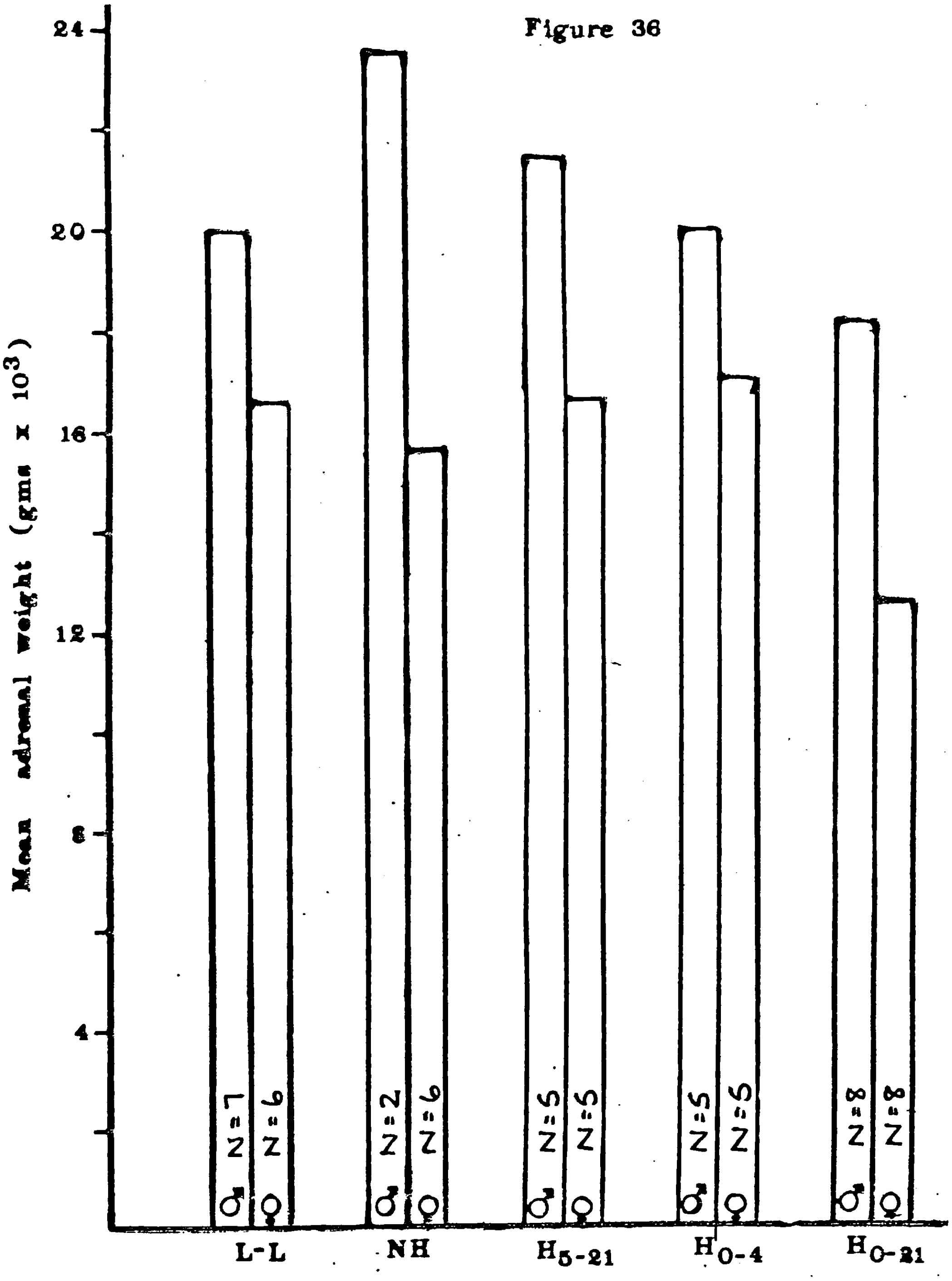
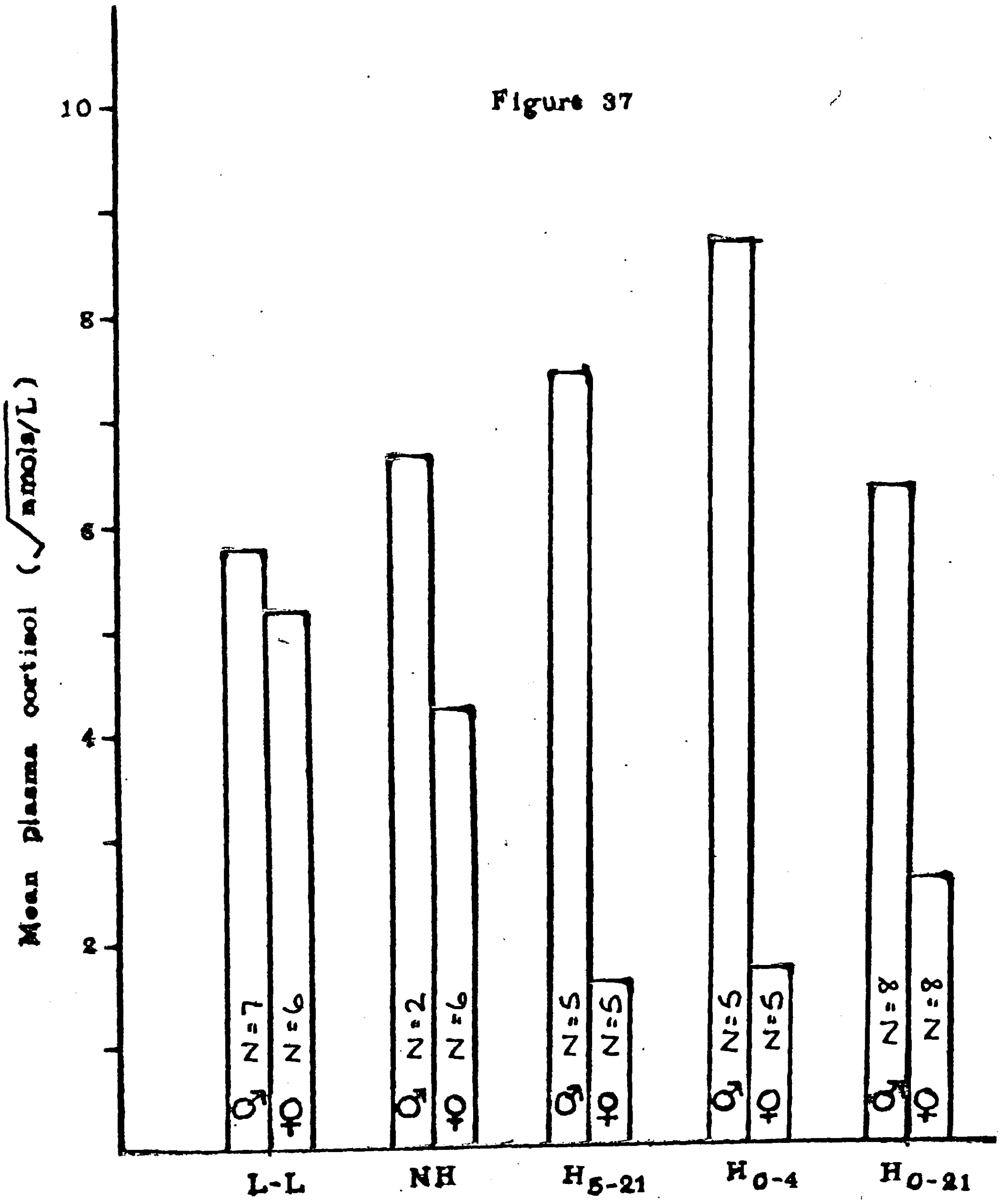


Figure 36

24
20
16
12
8
4
Mean adrenal weight (gms x 10³)
♂ N=7
♀ N=6
♂ N=2
♀ N=6
♂ N=5
♀ N=5
♂ N=5
♀ N=5
♂ N=8
♀ N=8
L-L
NH
H5-21
H0-4
H0-21

Figure 37. Plasma cortisol levels of animals from the handling conditions.

Figure 37


Mean plasma cortisol (√nmols/L)
10
8
6
4
2
♂ N=7
♀ N=6
♂ N=2
♀ N=6
♂ N=5
♀ N=5
♂ N=5
♀ N=5
♂ N=8
♀ N=8
L-L
NH
H5-21
H0-4
H0-21

In general terms it has again been shown that the females are less affected, partcularly behaviourally, by the experimental conditions than the males - as found in the previous sections. Throughout the results the group handled 0-21 days has generally been most affected in both behaviour and physiology; and this cannot be said to be in any way beneficial to the organism. The exact nature of the mediation of this handling effect is discussed below, together with an appraisal of the validity of the proposed hypothesis. The other handling conditions have tended to affect the animal to varying degrees, as expected, although not necessarily in a uniform direction.

It is very interesting that many of the results - when drawn as a function of the level of stimulation (assessed from the experimental hypothesis as increasing in the conditions control (L-L -> NH -> H_{5-21} -> H_{0-4} -> H_{0-21}) - produce a roughly U-shaped curve (see figures 29 and 35-37 for reference). Such a relationship between the level of stimulation and experimental results has been demonstrated in the literature on early experience, and is explained by Denenberg (1964) in terms of the Yerkes-Dodson Law (see also Smith, 1967).

Discussion

This discussion will review the findings with reference to the hypothesis put forward at the beginning of the section. The first question to be considered is that of the effect of handling (days 0-21), as such, in the hamster.

All the significant behavioural effects are found in the male animals with a consequence of increased emotionality, neophobia and impaired learning ability from the handling (see table 42). This result is in accord with the findings of Lawlor, Wells and Weinberg (1975), although the effects are not so dramatic. An explanation for this may be that the experimenter in this study was always the same, giving the animals a chance to habituate to E in some degree (see Bernstein in Newton and Levine (1968), p. 106), whilst in the above study the experimenter varied from day to day. Another possible cause for this less dramatic effect is that Lawlor *et al* used inbred stock, rather than an F_1 cross, as here, which would tend to accentuate any effects. The findings of increased ambulation have not been replicated here. Physiologically these animals were of poor physique with low brain weight - possibly indicating impaired brain development. Their cognitive ability, however, was not thought a consequence of this but rather a consequence of their general behavioural manner.

The decreased adrenal weights, together with low body weight, suggest these animals have been experiencing a stressful situation which their normal system has failed to adapt to - it is similar to the response to both desoxycorticosterone acetate and diethylstilbestrol (see p.66). although in these cases the effects are brought about by inhibition of the pituitary/adrenal axis rather than, as we would expect here, an increase in activation. Possibly handling leads to a general inhibition of the pituitary in this species.
In the case of handled rats that have been examined without being stressed there are no differences in adrenal weight within non-handled animals - decreased adrenal weight only occurring after a stressful event. The very high cortisol levels found seem to reflect this continual activity of the adrenal gland although there is no evidence to suggest a direct relationship between blood cortisol concentration and adrenal weight.

Table 42: Summary of effects of handling days 0-21 in the golden hamster, compared with control.

Dependent Variable		Response to test procedure in H_{0-21} animals: Males	Response to test procedure in H_{0-21} animals: Females
1. Behavioural Tests			
i)	Open-field ambulation	significantly decreased over all days.	decreased day 1 and increased days 3/4.
ii)	Open-field rearing	significantly decreased over all days	no effect
iii)	N/T R/T	significant increase R/T to first object. significant increase R/T to second object.	no effect
iv)	N/T T/O	significant decrease T/obj. 1	decrease T/O both objects.
v)	Discrimination Learning	significant T x C effect due to erratic later trials - good learning day 1	-
2. Physiological Measures			
i)	Growth	impaired	impaired
ii)	Brain weight	impaired growth	no effect
iii)	Adrenal weight	decreased	decreased
iv)	Cortisol level	increased (x2)	decreased

It could be argued that these high levels are due to a very rapid response to stress, as has been shown to occur in handled rats - even within a minute of the stress occurring.

An interesting aspect of the effect of handling in the hamster (i.e. depressed body and adrenal weights) is that it corresponds closely to the effects of cortisol treatment in neonatal rats - resulting in 'corticoid runts' (Schapiro, 1968). The theory that handling in rats enhances the general effect of an early stress response may be over-stepped in the hamster (which, in any case, has a more continuously active adrenal gland when a neonate than the rat) so causing a high release of adrenocorticoids.

Overall, however, these handled hamsters - whilst not being in such bad condition as might have been expected - are obviously very different animals from handled rats which have been described as showing improved biobehavioural characteristics. There is no evidence here that handling decreases emotionality, promotes growth and behavioural development, improves learning or increases the resistance to stress in the hamster as has been claimed for the rat. Further, this emphasises the importance of not assuming generalisation of theory between species.

The possibility that handling days 5-21 in the hamster would give similar results to handling in the rat appears unsubstantiated (see table 43). In the males this treatment results in low activity and exploration due to increased emotionality, together with an increased reactivity to novelty. Learning is also depressed and this is the only significantly different group on analysis. The females are also behaviourally affected showing depressed activity and exploration without the increase in reactivity. It is interesting that these behavioural changes tend to be more uniform over trials in this group than in other conditions. Overall, there is little effect on physiology in the mature animal although growth is somewhat depressed in young animals. Values for plasma cortisol are greatly altered, even more so than in the H_{0-21} groups though in the same direction, which could lend support to the suggestion

Table 43: Summary of effects of handling days 5-21 in the golden hamster, compared to control.

Dependent Variable	Response to test procedure in H_{5-21} animals	
	Males	Females
1. Behavioural Tests		
i) Open-field ambulation	decreased ambulation day 1 and day 4.	ambulation depressed uniformally over days.
ii) Open-field rearing	rearing very depressed.	rearing depressed
iii) N/T R/T	very decreased R/T on obj. 1	no effect R/T
iv) N/T T/O	decreased T/obj.1, increased T/obj. 2	decreased T/O uniformally
v) Discrimination Learning	scores slightly lowered overall	-
2. Physiological Measures		
i) Growth	both sexes show somewhat depressed growth throughout - midway between control and H_{0-21} groups. Mature weights ≡ control in males, slightly increased in females.	
ii) Brain weight	no effect	slightly decreased
iii) Adrenal weight	(slight increase)	no effect
iv) Cortisol level	increased	decreased

that these are not resting levels but stress-response levels due to a greatly accelerated stress response. A rapid response to stress, especially in the males who seem to show adaptation after some while in a test situation, may help to account for the effects on ambulation and exploration in these animals.

Physiologically these animals are unlike those handled days 0-21, nor does their behaviour tend to follow the same pattern. Obviously, a different effect has been produced by omitting very early handling as it does not appear so damaging but this group still does not approximate to what we would expect from handling in the rat. The tendency to find more uniformity in the behavioural effects suggests that the experience has served to 'reset' the animals functioning state, as hypothesised for rats, without causing the apparent (possible brain) damage of H_{0-21}. It may be that the overall amount of handling a hamster receives is the critical factor, with the early days simply being more heavily loaded than later in life.

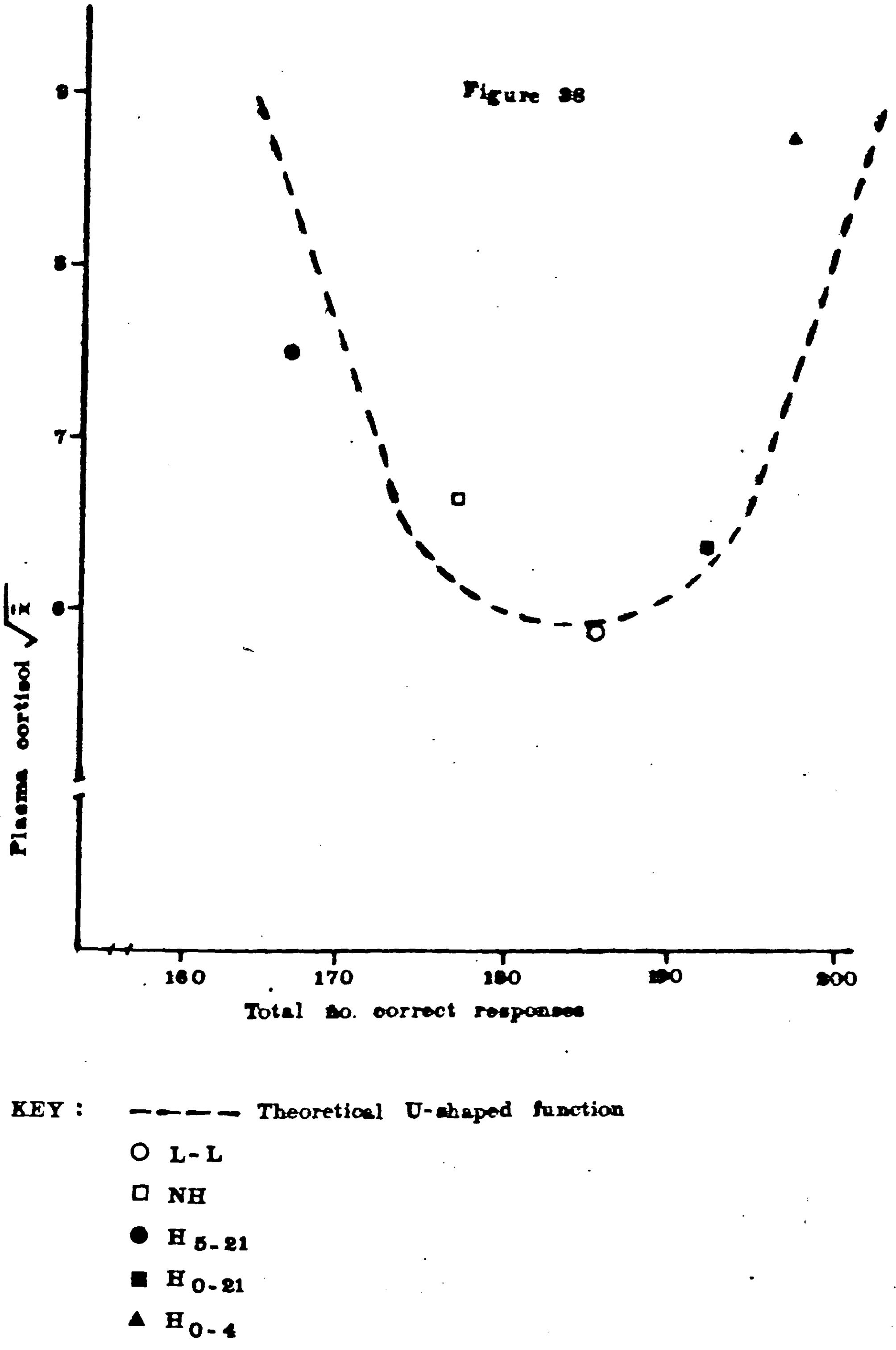
Both physiologically and behaviourally there is no evidence that handling days 0-4, in either sex, produces very deleterious effects; nor that it can account alone for the effects of handling days 0-21 (see table 44). Although body growth is initially depressed, as in H_{0-21}, in the young animals this is being overcome by maturity and is not evident in a mature animal. There is no effect on either brain weight or adrenal weight, although the cortisol levels again show a large increase in the male and a large decrease in the female. This continual finding of altered plasma cortisol levels in the experimental conditions, compared with the control, appears to confirm an alteration in the resting levels rather than in increased efficiency in the stress response, as a result of the early manipulation, although this is not found in rats. Support for this view comes from the fact that no evidence has been found in this species for correlation between circulating cortisol levels and adrenal size, hence the lack of effect upon the adrenals in these experimental conditions. Also there does appear to be a correlation between learning ability, which is known to be dependent on ACTH, and cortisol level, also dependent on ACTH, in the males (see figure 38).

Table 44: Summary of effects of handling days 0-4 in the golden hamster, compared to control.

Dependent Variables	Response to test procedure in H_{0-4} animals	
	Males	Females
1. Behavioural Tests		
i) Open-field	least depressed ambulation least depressed rearing	both rearing and ambulation ≡ H_{0-21} ie no effect on rearing; decreased ambulation day 1 increased ambulation day 3
ii) N/T	increased reactivity obj. 1	decreased reactivity obj. 2
	decreased reactivity obj. 2	(only group different from control)
	decreased T/O	decreased T/O
iii) Discrimination Learning	quick initial learning though erratic.	-
2. Physiological Measures		
i) Growth	depressed growth in both sexes initially (more so than H_{0-21}) - caught up by maturity.	
ii) Brain weight	(slight increase)	decrease
iii) Adrenal weight	no effect	no effect.
iv) Cortisol level	largest increase	large decrease

Figure 38. Correlation between plasma cortisol levels and learning scores (both influenced by ACTH) in males from the handling conditions.

Figure 38


Plasma cortisol $\sqrt{\bar{x}}$
9
8
7
6
160
170
180
190
200
Total no. correct responses
KEY :
– – – – Theoretical U-shaped function
○ L-L
□ NH
● H_{5-21}
■ H_{0-21}
▲ H_{0-4}

This may suggest an underlying alteration in the animals response to, or basal level of, ACTH as has frequently been suggested as an explanation of the handling effects in the rat. The fact that the overall effect may be different is immaterial.

Behaviourally, these animals all tend to show depressed scores although there is an indication that they are not so phobic as males H_{0-21}. There is little justification in these results for determining this early period as a critical period for producing deleterious effects of handling in hamsters. A few points do seem to indicate that this may be a critical period in some respects of development - for example, the general behaviour of the two groups H_{0-4} and H_{0-21} was similar in the test situations; both these groups showed quick initial learning but erratic responses on later trials; and the only groups from which any young pups were lost were these. It would appear that handling in this early period may well interfere with brain maturation and differentiation as suggested, but the effects produced by handling cannot totally be explained by this phenomenon.

Finally, the non-handled group provided some very interesting data and obviously was not equivalent to a second control group. Although none of the pups in this condition were actually handled, they were subjected to the same interference involved in the handling procedure - i.e. the cage was removed from the shelf and placed on a table, the top was removed, dog biscuit given to the female and a barrier placed across the cage to prevent access to the litter for several minutes; the top was then replaced and the cage returned to the shelf. The most outstanding effects (see table 45) are shown by the severe depression of rearing scores in the open-field together with increases in body and organ weights. The finding that this type of manipulation results in very definite results is most interesting from the viewpoint of female/pup interaction. Almost definitely some effect must be mediated via the mother as a result of separation from the pups despite the apparent lack of interest on behalf of the females, or the lack of communication with the pups. This must be concluded as all animals in this laboratory are fed daily with fresh, chopped carrot - a procedure that requires each cage to be moved and the top removed -

Table 45: Summary of effects in "non-handled" group, compared with control.

	Dependent Variables	Response to test procedure in NH animals.	
		Males	Females
1.	Behavioural Tests		
i)	Open-field ambulation	similar ambulation pattern over trials to control group (in both sexes) though somewhat depressed (in males more than females).	
ii)	Open-field rearing	very depressed (patterning again the same as control)	very depressed
iii)	N/T R/T	no effect	no effect
iv)	N/T T/O	greatly increased T/obj 2.	slightly decreased T/obj. 1
v)	Discrimination learning	good, steady learning	
2.	Physiological Measures		
i)	Growth	somewhat depressed in young animals though rapidly catching up, post maturity.	
ii)	Mature weights	increased	increased
iii)	Brain weights	no effect	increased
iv)	Adrenal weights	increased	no effect
v)	Cortisol level	slight increase	slight decrease

therefore the main difference between the control L-L group and the NH group is the actual separation and the feeding of dog biscuit. The fact that separation between a litter and the mother influences subsequent interaction, such as contact; and that the type of barrier (whether solid or perforated) influences the degree of this effect has already been noted by Villescas et al (1977). Many early handling effects have been found to be mediated in part by the interaction of the female and the pups with respect to care, maternal behaviour and interchange of physiological substances during nursing. This brings into view various questions relating to the mothering of pups by the hamster as it has been shown that maternal care is elicited maximally by pups aged 5-6 days, rather than newborn, and that the behaviour of the females seems different over the first few days (see data from video time lapse recording). Perhaps the hamster has a physiological system designed to deal with somewhat inadequate maternal care during very early life; and it is this which is resulting in the unusual effects of manipulation in this animal.

Conclusion

The findings in this section of the research lead one to accept that:-

(i) Handling in the hamster days 0-21 produces deleterious effects dissimilar, and generally in the reverse direction, from the effects produced by handling rats days 0-21.

(ii) Handling in the hamster days 5-21 does not produce effects commonly found in handling rats, although the outcome of this procedure may be similar in its mode of action and less damaging than handling days 0-21.

(iii) Handling in the hamster, days 0-4, is less damaging than expected and cannot be designated as a critical period for the production of handling effects in the hamster.

(iv) The non-handled group does not act as a second control group, but rather provides evidence for the mediation of some of the effects found in this research.

SECTION 4: GENERAL DISCUSSION OF RESULTS AND TESTING PROCEDURES

SECTION 4: GENERAL DISCUSSION OF RESULTS AND TESTING PROCEDURES.

Having detailed the experimental results by section, there are several general points for discussion. When designing these experiments the decision to use the testing procedures utilised was made largely in view of the fact that these were commonly used procedures, and to replicate results with the golden hamster would (a) demonstrate the usefulness of such procedures across species and (b) allow one to make certain basic comparative equations between species, their known behavioural and physiological differences, and their responses in test situations. Repeatedly, however, as mentioned in the previous sections, there appeared little continuity in the results obtained in the golden hamster - nor any correlations as might have been expected between results. This does appear to be at variance with results obtained in similar experiments with, for example, the laboratory rat where, again for example, the condition of the adrenals may be used to reflect the general condition of the animal (Jelinek, 1971) whilst such measures in the golden hamster appear much less predictable (Denyes & Horwood, 1960; Peczenik, 1942b).

In general, it is obvious that the females have been less affected by the experimental conditions than the males, particularly with regard to the behavioural measures used. This has not always been reported, for this species (see Swanson, 1969) although has generally been believed for many other experimental species and so cannot be attributed to the golden hamsters sexual dimorphism. It is thought that the female experimental subject is better "buffered" against environmental variations due to the presence of the female hormones - in particular progesterone. It is interesting, however, that the golden hamster is particularly susceptible to the influence of this hormone (Hoffman <u>et al</u>, 1968) although whether this makes them even less susceptible to behavioural change than, say, the female rat, is unclear. Sex differences were shown throughout in (i) growth rate and body weight, with the females showing faster growth and greater overall size, although not as early as might have been expected (Swanson, 1966); (ii) open-field ambulation and rearing, with the females giving the higher scores, again as expected (Swanson, 1967); and (iii) adrenal gland size, with the females having the smaller glands (Gaskin & Kitay, 1970). Although there is no evidence to suppose any correlation between adrenal gland size and plasma cortisol levels (see Denyes and Horwood, 1960), a fairly consistent sex difference was also shown in the cortisol levels obtained, with the females generally giving lower readings than the males. This finding is contrary to the data given by Gaskin & Kitay (cited above) who demonstrate the resting plasma steroid levels to be similar in the two sexes although under stress the female gives lower readings than the male. This, that is, the level of 'stress' under normal laboratory conditions, may explain some of the discrepancies found in the literature (see Chester Jones, 1955; Zeiger et al, 1975 and Gaskin & Kitay, 1970 for comparison). There is very little evidence from the analyses to suggest that the sexes have responded differentially to any of the experimental conditions - the only S x C interaction attaining significance being those for growth in mature animals in sections 1 & 2 and brain weights ($p < 0.1$) and cortisol levels ($p < 0.05$) in section 3, the handling conditions. The finding of no sex difference in open-field behaviour following environmental manipulation (section 2) is the one clear example where the experimental condition has influenced behaviour in the sexes differentially (to the extent of losing the normal sex difference) and replicates the finding of Swanson (1969) that early environmental exposure can alter later open-field behaviour in this species.

As stated in the previous sections closer study of maintenance and social behaviours in a study of this nature may well provide important clues to the mediation of experimental effect. For example, in the second section of these results the data on maternal behaviour,* obtained from video time-lapse recordings demonstrated - even when only crudely analysed - very clear and significant differences in the behaviour of the female under altered conditions. These differences were reflected in her

* detailed and discussed in Appendix A.

individual behaviour (such as use of cage space and responsiveness to intrusion) as well as in her interaction with the litter. There is some evidence that the females oestrus cycle increases activity away from the nest on the day of oestrus - and that there may indeed be an artificial cycle in the laboratory animals due to the 'weekend' effect (Richter, 1976).

A secondary finding of these recordings was the reaction of these animals to the daily feeding of carrot - a very clear demonstration of how something habituated to by the experimenter remains a dramatic disturbance to the experimental animal. Such a response must be eventually reflected in the animal's overall manner (as has been demonstrated by the 'non-handled' group of animals in section 3) and underlines the need for well-reported descriptions of standard laboratory conditions. Variables such as these - including whether animals are caged randomly or by litter, whether grouped or isolated - need careful consideration when assessing experimental design.

To return to the manner in which ethological approaches may be useful - the fact that pups reared in an early burrow or free enriched environment appear more light entrained could only be assessed by such an approach. If the impression from this study were verified it may explain the root of some of the infantile stimulation effects in that fundamental physiological processes are governed by the circadian cycle. That early priming in an organisms 'running' cycle occurs seems shown by the lack of evidence for any change in the light entrainment of the adult hamsters in an identical free-enriched environment (Section 1).

The testing procedures used included the open-field, the novelty box test (as used by Wells, 1975, for rats) and the SMVDA in addition to physiological measures of growth, brain size, adrenal gland size and plasma cortisol levels.

The open-field test is a standard testing procedure for many species and is particularly used in the field of early experience to determine the emotionality of the test animals. Standard data are therefore easily available for comparative purposes. However, as has been mentioned in the text, it was felt that the standard open-field measurement technique did not adaquately demonstrate the behavioural differences of the experimental animals from differing conditions. Two workers (Sykes, 1970 & Swanson, 1966) have already suggested that interpretation of open-field behaviour in the golden hamster would be aided by observing the total range of behaviour within the field and this was attempted crudely in this study by observing washing and the ease with which an animal would cross the centre of the field. Subject to analyses these observations revealed handling conditions to depress both activities in both sexes, whilst the environmental conditions tend to increase washing in the males and the ease with which females cross the field. There are therefore good indications that these incidental measures do vary with sex and experimental condition in such a way as to justify their inclusion in open-field technique.

A recent paper (Gallup & Suarez, 1980) supports the possibilities for ethological analysis of open-field behaviour, with a view to altering the traditional perspective on open-field behaviour as an index of fear and/or general emotionality and so avoiding some of the problems that have arisen in interpretation of data (see Whimbey & Denenberg, 1967 & Aitken, 1974.) The suggestion is that open-field movement is an interaction between tendencies to evade predation and to reinstate contact with conspecifics. These ideas are well suited to the experimental animals (chicken) used by Gallup & Suarez but may appear less appropriate in a species such as the golden hamster where attachment to conspecifics is less obvious - territorial claims usually seeming more important. However, such an interpretation may clarify the behaviour of certain animals in this study who attained high ambulation scores whilst subjectively appearing highly fearful.

The novelty testing was used in this study following its use by Wells (1975) in this department with handled rats which produced highly significant and replicable results. However, again as mentioned in the text, it appears somewhat inappropriate for use with this species. Problems that occur are largely due to the hamsters passion for digging in the corners of test fields and this may be averted by re-designing this test using a circular field.

The discrimination used in the SMVDA (black/white) proved to be a little too simple in some respects as the ceiling for learning was reached easily, particularly in those groups that had derived benefit from their experimental experience. The data collected for trial times proved beneficial in determining the differences in rate, in addition to aquisition, of learning. At least in certain groups, such as the handling conditions, data on number of error responses may have been useful but is more difficult to obtain accurately.

The general finding of improved learning in these animals compared with other standard data obtained in this laboratory (see Lawlor <u>et al</u>, 1975 & Sykes, 1962), was thought to be due to dietary, and strain, differences. The statement of Tolman (1954) ".....that agitation, or excessive emotional arousal, disrupts the learning process is supported by general observation of golden hamsters" does not seem totally justified following these results.

The use of general growth is an obvious physiological measure of the animals general well-being. However the use of adrenal function indicators in this study was largely dictated by the need to find some simple measures that would provide comparable data with other species. The use of adrenal weight and plasma steroid level are therefore self-selecting although further measures, such as brain DNA, could be useful. However, the use of brain tissue weight is supported as a measure of cortical development, probably reflecting other structural and chemical differences, by Rosenzweig <u>et al</u> (in Newton & Levine, 1968). The physiological data, as a whole, may be simply indicating effects due to the small sample size used. A further, more detailed, study could well verify the finding that the early pre-weaning experience is important in 'setting' the animal in behaviour and physiology.

A slight problem may have arisen with the results of adrenal size due to taking no account of the stage of oestrus the females were in. Peczenik (1944) found that the female adrenal varied with the oestrus cycle and could give great variation in results, often equalling the size of the male gland during metoestrus. Indeed the data obtained does give a wider range for the female adrenal weights than the male weights, and this is verified by a slightly larger standard deviation (S.D. female = 3.56; S.D. male = 3.23).

The cortisol assay relies on a number of separate materials and on the radioactive counter to give results and although many workers appear to ascribe the results with absolute value the experience in this case was that they are at best approximate indications rather than replicable absolute values.

The technique used to acquire "stress-free" blood samples in the golden hamster does give values for plasma cortisol levels (see table 46) that accord with the given value in the literature of 18 nmol/L (Westphal, 1971). The use of ether and stunning were suggested by the staff of St. Thomas' Hospital, and these samples were obtained there.

Table 46: Plasma cortisol levels in the golden hamster female (with replications) obtained by various methods of anaesthesia prior to obtaining plasma sample.

Anaesthesia	Plasma cortisol (nmols/L)		
	1st Assay	2nd Assay	3rd Assay
Carbon dioxide	0	0	-
	2.5	17.5	-
Ether	257.5	240	117.5
Stunning	14.25	0	-

The use of carbon dioxide was suggested later from another source and does appear a reliable method of obtaining stress free samples although not for all types of assay due to the possible interaction of the gas with the biochemical properties of the blood. However, the values obtained from the experimental animals in the physiological sample give much greater variance making positive statements about whether these are true resting levels or are reflecting some degree of stress response difficult (see appendix F for individual results). The finding of Gaskin & Kitay (1970) that resting plasma steroid levels in the golden hamster show no sex difference whilst 'stress' plasma steroid levels show higher male values than female values may encourage one to describe some of the values obtained here as stress values. Male titres all tend to be higher than female titres and even when the females give high readings they are nowhere near as high as in the male.

It may be that the males, who showed most experimental effect, may simply have been more reactive to the unavoidable disturbance associated with collecting experimental data (although all animals were given time to adapt after being moved from the animal room to the room where physiological data were collected). In effect, the methodological problems associated with collecting any stress-related data have been repeated.

With these reservations, then, concerning the test procedures themselves, the experimental conditions and the effects produced are discussed in relation to other studies in the following chapter.

VII: GENERAL DISCUSSION

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The main points proposed in this research are answered relatively simply from the results, either positively or negatively, although how these effects have been produced requires more explanation. The initial propositions made in this thesis (see Chapter II) were concerned with the consequences of environmental manipulation, per se, on an experimental animal. In the golden hamster it is demonstrated that such manipulations are effective; that preweaning experiences tend to determine the effects of later experiences; and that a quiet early environment is advantageous whilst a more stimulating environment disrupts the animal's development as a competent adaptive organism.

The finding that the preweaning experience is important in "setting" the animal accords with most other findings in several species although the latter, more specific, effects are at variance with those for the rat. Many experiments quoted in the literature have studied the contribution of the animal's pre v. post-weaning experiences to its adult physique and personality - with a high concordance in the predominant effect of the preweaning environment (see, for example, Schaeffer & Darbes (1972) and Essman (1971)). It was found here (see section 2 of previous chapter) that the preweaning environment - whilst being most important in "setting" the animal's physiology and hence behavioural responsiveness - was by no means alone in contributing to the adult animal's make-up but rather acted interactively with the future experiences of that organism. It demonstrates the crucial aspect of an individuals environment in that that early environment may alter an apparantly inchoate neonate with regard its future receptivity and reactivity. A slight caution must be made concerning the feeling that one may eventually understand all aspects of an environmental force upon an organism, and so produce "clones" using the environment as a mould (see Denenberg in Ambrose, 1969, "planned life histories"). This is in some ways an overall view for idealistic debate but in practice interpretation of such studies becomes too complex and cannot truly accomodate variance in the genetic pool and individual differences which are an inherent aspect of every organism.

Looking for a moment at the consequences of an enriched environment they were, behaviourally, similar to those of such an environment in the rat - i.e. increased ambulation, probable decreased emotionality, increased reactivity and improved learning ability. Physiologically, however, the effects were a decrease in brain weight, no effect on the adrenal and a decrease in plasma cortisol levels. The outstandingly contradictory result here is that of the reduction in brain weight, particularly in the males. The work with rats, which invariably only uses males, gives fairly consistent results for increases in this measure and this is taken to indicate improved cortical development due to the correspondence between cortical thickness and tissue weight (see Rosenzweig et al, in Newton & Levine, 1968, p.266). This improved development may be considered the physiological consequence and mediator of improved learning ability. Body weight was not also found to decrease in the golden hamsters as a consequence of enrichment - the actual decrease in brain growth being in any case, an absolute rather than a ratio value. Nothing seems to adequately explain this decrease in brain weight - although a lack of effect may have been explained by the constraints of skeletal growth (male rats, as used in enrichment studies, being unusual in their capacity for post-pubertal skeletal growth and hence, possibly, their cerebral growth). Although these results may not be in accord with 'typical' results such a view is governed largely by the view and interpretive stand taken by the researcher. It seems likely almost any effect may be found due to the wide variation in what constitutes an enriched environment in different laboratories. It is the feeling of this researcher that environmental enrichment effects are largely concerned with cognitive psychology and, where general behavioural effects are found, that these are a consequence of: (a) adaptation of the organism to a total disruption of its normal behaviour as may occur where toys and social groupings are being changed daily (Van Woerden & Raaijmakers, 1975). The fact that such daily change may be harmful was adequately demonstrated by the effect of enrichment, in the form of daily change of play objects, for golden hamsters (Lawlor et al, 1975); or (b) advantageous social facilitation as may be expected to occur within a free enriched environment of weanling rats.

To return to the more specific, contrary effects demonstrated in this research, the effect of a quiet early environment in the golden hamster appears to have more advantageous consequences than such an environment may have in the rat.

For instance, although no references were found in the literature for the effects of a comparable quiet 'burrow' rearing condition, various effects of dark-rearing in rats are known. These studies have mainly been concerned with investigation of visual perception (- the only impairment having been shown in pattern discrimination due to the much longer training required: see Hebb, 1937 in Sluckin, 1971 pp 106-7). However, several reports conclude that the dark-reared animal is more "emotional" due to "........a greater reluctance to eat in a novel environment.."(Gibson et al, 1959) and ". .a tendency not to enter the arm of a novel maze completely..." (Walk, 1960). Tees (1969) demonstrated greater defecation and less ambulation in the light in the open-field although Gibson et al (1959) showed no differences in this measure. Although the data for open-field behaviour in the golden hamster reared in an early quiet environment, on day 1, show low activity this may be better understood as caution rather than fear;together with data from the other behavioural testing procedures,this is in accord with proposals suggested in chapter II. That is, in a small rodent, some cautiousness when entering a novel environment is surely an indicator of a well-adapted animal and, indeed, the above results for the rat, may also be open to this alternative interpretation.

One problem of comparison with this study and the literature is that the rearing of rats in darkness can be continued up to 90 days, and also the darkness is usually total. This does not appear to affect visual development as both the rat (Sluckin, 1971) and the golden hamster (Schiffman, 1971) have shown visual cliff response following such experience. However, if a rabbit is so treated it suffers biochemical damage to the retinal ganglion cells which only recovers after some while (Beach & Jaynes, 1954). In effect, this latter result shows the situation of total darkness to be too artificial and is not what was being aimed for in this design. The very low-light level used here served to ensure there would be no visual damage and was the closest approximation available to a true burrow where the pups emerge for short periods in the light as soon as they are active (see Daly, 1971). Even very low levels, or short periods, of illumination may influence the animal's physiology and adrenal gland activity in a similar manner as those influencing the animals' biological clocks. This point leads one back to the apparent difference in light-entrainment of the two conditions.

Physiologically, a monotonic relationship has been demonstrated in the rat between adult body weight and the level of illumination in the rearing condition (Lockard, 1963) and a dependency on light levels for sexual maturation (Fiske, 1941). Fiske & Lambert (1962) also demonstrated the influence of light on adrenal weight in rats and this also appears true for the golden hamster - dark rearing leading to a significant increase of adrenal size in the males: in the rat light rearing leads to a reduced adrenal size in the females. The fact that diurnal rhythms in plasma corticoids, 17 - ketosteroid excretion, the release of adrenocorticotrophin and the number of circulating eosinophils may be shifted by reversal of the photoperiod strengthens the case for light regulating adrenal gland activity. Indeed, Mos et al (1974) concluded that light rearing affects the maturation of the hypothalamic - pituitary - adrenal axis and the stress response in two strains of mice by similar results.

The fact that those animals reared in the burrow condition appeared to display economic, adaptive behaviour, both in the experimental condition and during testing, gains support from the finding that gerbils reared in a more natural environment display a similar adaptation in that the physical rearing environment determines the behavioural repertoires and degree of domestication shown (Clark & Bennett, 1977).

In summary to these results so far discussed it therefore appears the proposals put forward earlier in the text are substantiated. A caution before accepting the advantageous aspects of quiet non-stimulating early environments and stimulating post-weaning environments is that these results have been obtained using a species, the golden hamster, known to differ in various regards to other common laboratory animals, notably the rat, particularly with regard to its response to infantile stimulation techniques. A comparative study utilizing a less traumatic experimental design seems appropriate.

The other contrary result obtained in this research is that handling in the hamster has a disruptive effect upon the organism. This fact may have biased the above conclusion to some degree although the proposition was put forward as one of general applicability to small rodents. The results obtained from the handling conditions as proposed in Chapter III are greatly at variance with those accepted as typical in the rat.

From the summary of effects of the standard handling technique given by Denenberg (1962b) all the measures replicated here have given opposite results in the golden hamster - i.e. impaired learning, increased emotionality, decreased exploratory behaviour, lowered adult body weight and higher plasma cortisol levels in the males. In the female golden hamster there is more tendency for the results to approach those of the rat than in the male. It therefore seems that in the golden hamster the effects of handling are, indeed, not in keeping with the 'typical' effects described in the literature - so ruling out the possibility of broad generalisations for this technique.

The fact that Swanson (1969) in the first finding of handling effects in the golden hamster only handled on a few brief occasions during the preweaning period eliminates the only solid contradictory evidence for this conclusion - due to the lack of comparability in experimental design. That there is a strain difference in the severity of the expression of the results cannot be denied but it seems difficult to accept that one strain would respond in the opposite manner.

The general conclusion of Levine, Haltmeyer, Karas & Denenberg (1967) that stimulation in infancy results in a less reactive animal, both behaviourally and physiologically, does not hold true for the golden hamster where infantile stimulation (i.e. handling) results in a highly reactive animal which appears almost incapable of exhibiting "resting" levels of anything.

Having established this failure in cross-species replication an explanation must be proposed. Various differences exist in both the physiology (see below) and lifestyle of the common laboratory rodents which must be considered rather than attempting to describe widely 'typical' effects.

For instance, a large area of study involves the early environment of the pup with respect to the mother, the litter and the general social environment. In lieu of proper field studies into the natural history of these animals some assumptions must be made from the evidence available. The first few days of handling in the rat have been suggested by Denenberg to be the most important and this is the very period proposed as a critical period in producing the deleterious effects of handling in the golden hamster (see chapter III). An indicator of a change in the females behaviour toward the pups at this point was found from the video recordings in this study, in that the female changes her pattern of time on nest - however, this also appears to occur in the rat (see Schaeffer, in Newton & Levine, p. 118) around the fourth day and therefore must be interpreted as a natural fundamental behaviour pattern in the rodent mother. The fact that the responsiveness of the female toward the pups at this age is different in the rat and the golden hamster provides an independent variable. It was concluded in chapter VI, section 3 that this early period was not the critical period in producing the handling effects in the golden hamster but may well be the most effective in altering physiological development.

Further variation occurs between the rat and the golden hamster in respect of the amount of hypothermia (at one time considered to be the important variable for producing handling effects) the pups may be expected to incur and the results thereof. The degree of hypothermia that may be expected in a laboratory (usual temperature around 20°C) would be greater than that would occur in a natural burrow (usual temperature around 30°C) so the length of maternal absences may be important. However, very good nests are usually built by the hamsters, compared with the rats, in these conditions so minimising exposure of the pups. The fact that hypothermia produces a specific ultrasonic call in pups, as distinct from the call produced by unusual tactile stimulation (see Noirot, 1972), and that these calls develop at different rates in the golden hamster compared with the rat together with associated physiological changes (see Okon, 1971) again provide a differential medium through which the handling may produce altered effects.

The fact that handling pups alters the maternal behaviour has been repeatedly demonstrated for both rats and mice (see Priestnall, 1973) - one of the components of the maternal behavioural reportoire that is affected being the amount of licking that occurs. This licking of the pups is important in prompting the reflex of elimination and has been shown to increase with handling. Assuming a fairly direct relationship between the amount of licking and the amount of elimination, there may ultimately be some effect on the electrolyte balance within the neonate. The golden hamster is particularly susceptible to bouts of diarrhoea and all the pups lost in this study showed signs of such a problem. The fact that the hamster responds to cold stress by altering its electrolyte balance has been demonstrated (Denyes & Horwood, 1960) and is a consequence of it being a hibernator, and appears irrespective of any adaptation to natural 'desert' conditions. The fact that studies of cold stress in the golden hamster have also demonstrated changes in enzymatic activity and adrenal medulla activation as implicated in handling, stress and emotionality studies in the rat lends support to the conclusion that the overall physiology of any given species must be considered effective in producing the specific results of an experimental manipulation although certain of the mediating channels may be similar.

This brings the concentration on adrenal cortical function in this field into some dispute and it is encouraging to note some concentration on the activation of different physiological systems by various stressors - both physical and psychological.

The fact that changes in maternal behaviour are thought of as a mediator in producing effects of infantile stimulation prompted the inclusion of the "non-handled" condition in this experimental design. The supposition was that by comparing the 3 groups Ho-21 (separated and handled), NH (separated and non-handled) and L-L (untouched control) one may be able to eliminate or determine certain variables. That the NH group did not act as a second control group demonstrates that separation per se, even when apparently undisturbing for the animals, does provoke some result. It was just such a "second control group" that led Levine & Lewis (1959) to accord handling effects to "any of several forms of extra stimulation". It was this attitude that has led to much of the confusion in the field with reviewers attempting to equate results from totally disparate conditions. Rather one must concentrate on the small variations and use them to indicate why one is not getting uniform results. Increasing numbers of reports in the literature on the effects of maternal separation together with technological improvements in monitoring procedures for all aspects of mother/pup interaction should clarify this aspect of early handling mediation.

A final point to make concerning the effects of "non-handling" is that this milder form of stimulation appears to produce effects that are less rigid and more easily reversed; in a similar way early experience effects become less permanent in animals of an higher evolutionary status.

As mother-infant interaction has been found an important mediator in producing many effects in this field it may be useful to look more closely at the known social structure of some rodents. The golden hamster has already been discussed in some detail in the previous sections and one may conclude, in general, that the animal is solitary in its natural surroundings and that the family group disperses as soon as the young are independent (Rowell, 1961a). The only laboratory rodent that comes from a similar environment to the hamster is the mongolian gerbil - and its family environment has recently been under investigation. The males of various rodent species are known to partake in the care of young - examples being *Mus musculus*, several *Peromyscus* species and others (see Waring & Perper, 1980 for full bibliography) - and this is also true of the gerbil. The presence of the male has been shown to influence both the development of the young (as is also true in *Mus musculus*, Smith & Simmel, 1977), and the patterning of maternal care (Dudley, 1974; Elwood, 1975), to the extent that within a family group, the pups are rarely left unattended in the nest for any length of time. A recent controversy over the effect of the male on pup mortality has shown the male to be particularly sensitive to the effects of environmental disturbance (Ahroon, 1979; Gerling & Yahr, 1979). Both parents are also sensitive to litter size - with deteriorating care being associated with larger litters (Elwood & Broom, 1978). Although this species therefore differs greatly in the parental care given to the pups compared with golden hamsters they appear sensitive to similar disturbances, and might be expected to provide one of the critical experiments required in the field of early handling; i.e. one may expect some similarities in physiology between the hamster and the gerbil, which may enable the investigator to split the variables of parental care and basic physiology as mediators in producing the effects of handling.*

In studies of colony living this paternal care of the young has been less obvious, at least in the mouse, with other females of the colony aiding lactating females in their care of the young (Gandelman *et al*, 1970). The manner in which a colony population is built up varies with different species, and this may reflect in turn on the social organisation and role-playing within that community. Typically, mouse colonies may be quickly built up to a fairly high density which is well socially

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*It has now been reported (Lown, 1979) that handling gerbil pups days 1-21 significantly decreases open-field ambulation.

organised (Butler, 1980; Henry et al, 1975). Only if the population becomes overcrowded and the social organisation is interfered with (for example, by removing the young), does the colony break down, fighting breaks out and reproduction ceases. This cessation in reproduction, together with poor viability of the young, also occurs at peak population to control density. In gerbils, who have a similar family arrangement to the mouse, a population is very difficult to build up due to the founding pair(s) being dominant - this pair breeds and sexual maturation is repressed in the young unless removed from the presence of the parents (Goldman & Swanson, 1975; Payman & Swanson, 1980). In golden hamsters, again, it is difficult to build up a large population as the females show impaired maternal behaviour in neglecting to isolate themselves and their litter sufficiently - so the young pups tend to be cannabilised. The control of population density in this latter species is therefore associated more with inadequate adaptation to a social environment rather than a built-in strategy for dealing with such a situation.

The fact that colony living alters, specifically, levels of aggression that are displayed may well be an underlying cause of these effects. In gerbils little has yet been published on this aspect but it would seem that aggression is controlled due to the physiological dominance of the breeding pair. In mice, crowding does not increase aggression - rather, this occurs in the mouse when isolated (Brain & Evans, 1973) - and this appears reflected in the inverse relationship found by Svare & Leshner (1973) between aggression and fear. It is interesting that the relationship found by these workers in the mouse (of inverse relation of fear, and direct relation of reactivity, to aggression) is not the same as the relationship found here in golden hamsters - i.e. the handled animals were most aggressive, most fearful and most neophobic. In the golden hamster, however, crowding leads to an unusually high incidence of aggression in the males which must be effective in producing the severe disruption in maternal behaviour. It has been suggested (Payne and Swanson, 1973) that the normal lack of aggression in the male golden hamster is adaptive in that the male is only interested in the female sexually and is not aggressive (see also Steel, 1979 & 1980). This would mean that the females were not being 'stressed' by the males fighting which would otherwise, as found in the laboratory colony, lead to impaired fertility, abortion and disrupted maternal behaviour.

Such studies serve to increase the details known concerning specific species and the likely mechanisms activated and effective within a given situation, in addition to emphasising that behaviour, its regulation and consequences, is species specific.

The physiological effects of handling in the hamster found here (i.e. depressed body and adrenal weight) are those also found as a result of pituitary and adrenal biochemical inhibitors. In rats the handling process is thought to lead to improved growth by enhancing the activation of the pituitary via the effects of an early stress response. However, this 'early stress response' is occurring late in the preweanling rat due to the 'stress-non-responsive' period (S-N-R period) discussed by Schapiro in Newton & Levine (1968) p. 214 which may last until day 14. Variation in experimental result therefore appears a consequence of the variation in maturation of different central pathways or connections mediating qualitatively different stresses. For example, various noxious stimuli on groups of rats, days 0-21 resulted in no significant differences in open-field behaviour or learning ability when the rats were tested at 60 days (Griffiths & Stringer, 1952), whereas Levine & Lewis (cited above) accord several forms of extra stimulation with producing handling effects. Very early administration of cortisol (the release of which is the consequence of a stress response in the rat) results in similar effects to handling in hamsters (see above reference, p.224).

Olton, Johnson & Howard (1975) also found that rats given corticosterone in infancy had impaired active avoidance ability together with interfered brain and body growth. As data are unavailable for the S-N-R period in the hamster and the literature (see Hillman & Seliger, 1975) suggests that this may not occur in this species the handling effects may be simply due to a very early stress release of adrenocorticoids which the neonatal homeostatic mechanism is inadequate to deal with. This may in turn lead to a general inhibition of the pituitary or, as is suggested to occur in the cortisol-treated rats, an effect on thymus maturation and programming. The endocrinological interrelations between these systems cannot be ignored.

Another endocrinological system known to differ physiologically in the hamster, and shown to decrease its activity as a function of handling in the rat (Ruegamer, Bernstein & Benjamin, 1954), is the thyroid. The relationship between lower thyroid activity and better food utilisation is important as the rats in the above study all had similar food intake although only the handled animals showed improved growth. This relationship also appears true in the human (Powell et al, 1967) and the chicken (Woodgush, pers. comm.), so one may tentatively assume the same relationship for the golden hamster. To follow through this argument, handling in the hamster would have to activate the thyroid so producing the impaired growth seen- such an activation does not easily accord with the proposed pituitary inhibition, suggested above.

It is not only the variation in maturational time scale that is important but also the fact that different "stresses" may exert their effects to greater or lesser degrees and/or upon different physiological systems. Examples demonstrating this point include: the finding that handling and environmental complexity have differential effects on behavioural and physiological development (Morton, 1963); perceptual and social environmental enrichment have different behavioural effects as a consequence of activating different physiological machanisms (Gardner et al, 1975); the susceptibility of the female to different types of maternal stressor in studies on prenatal stimulation effects (Anderson, 1968); and the activation of the adrenocortical steroid response and/or the adrenomedullary catecholamine release in response to various social encounters (Hucklebridge & Nowell, 1974). This latter study is interesting in that it considers both aspects of the adrenal response to stimulation rather than only one in isolation.

That the variation in the maturation of both neurological and endocrinological mechanisms must be assessed for the various species and strains commonly employed in research is imperative before adequate interpretation of the consequences of environmental manipulation may be made. Examples of experimental results which vary by strain are legion (particularly in mice) - e.g.: the hypertrophy of the adrenal cortex as a result of crowding in mice is dependent on strain (Bronson, 1962); and the effects of undernutrition varies with different strains of mice (Castellano & Oliverio, 1976). Both of these effects tend to be thought of as typically consistent across species.

Variation in postnatal development within a species has been discussed by Mühlbock & Tengbergen (1971) and between species by King (1968). That such effects have been less apparent in rats may be due to the narrower variation in rat strains commonly employed in this field of study. The findings of variability both overall and in the severity in the effects of handling in the golden hamster may be attributable to a genetic variation.

This variation in experimental effect by strain is part of a large problem within the study of animal behaviour. The compounding of experimental results are often attributed to this variable and that of sex, as apart from experimental design, and as Schell & Elliott (1967) state "....for the moment, the point is clear that sex does make a difference in response to stress. The direction and degree of difference varies with the stress and probably with the strain of animal employed, although this latter point requires and deserves systematic exploration". A comprehensive review of these aspects of research appears long overdue, rather than each paper repeating the need for it.

To return to aspects of adrenal cortical activity, as such, it has been shown that handling in the rat leads to a reduction in plasma corticosterone; and that in the rat there is a close correlation between behaviour parameters, levels of circulating hormone and adrenal responsiveness - although Ader (1969) questions whether adrenal steroid levels in 'novel' situations are truly related to behavioural emotionality. However, there is little evidence for such close correlation in mice or monkeys (Speirs and Meyer, 1949; Sackett et al, 1973). In the male hamster handling has led to an increase in plasma cortisol level, although the females have shown a decrease; and there does not appear to be any correlation between these levels and the amount of open-field ambulation occurring. This strengthens the similarities between the mouse, rather than the rat, and the hamster as suggested previously due to the variability in handling effects. Watson et al (1974), using CBA strain, showed no difference in plasma corticosterone as a result of handling. It is interesting that Samorajski et al (1971) found no effects of stress on mouse behaviour despite obvious physiological changes - as appears to have occurred here in the female hamster.

Aside from the obvious further questions posed by this research and the need for more adequate reviews of the various aspects of this field of study - surely a possibility in this computer age - the need for a more general overall view by researchers must be emphasised. Blindness to the effective aspects of general care, housing and diet of laboratory animals is inappropriate. General behavioural trends as a consequence of each species circadian cycle must be noted together with ethological analysis of testing procedures, to provide greater detail on the actual consequences and variability in experimental result. Conclusions attributing results to species - specific social organisation and/or endocrine organisation (as suggested by Brain & Evans, 1973) demonstrate the inability of workers to see animals as a whole rather than as unrelated systems. It is indicative of this attitude that if one compares the approaches to investigations in animal behaviour with those in human research their appearance of experimental methodology is reversed - i.e. pharmacological output being investigated first in the animal studies, followed by physical insult, change in nonsocial sensory output and finally change in social stimulation, which is always considered primarily in human research (see Richards et al, 1976).

Earlier in this thesis the extrapolation of infantile stimulation theory to human infants has been mentioned and the validity of such thinking questioned. If nothing else the research detailed here serves to emphasise that such thinking is, at the least, premature. Difficult as it is to resist the temptation to find immediate human analogies in some of the dramatic effects which have been reported - it is a temptation which must be resisted given the present level of understanding. If the strategies employed in studies on small rodents are unclear in their result the application of these strategies and concepts to organisms of a much higher evolutionary class cannot in all conscience be made. Rather than attempting to formulate broad concepts the detailed study of specific physiological systems, species-specific behavioural consequences and the mediating channels of early experiential manipulation will serve to provide more relevant channels of investigation, and possible effectiveness, in primates and man.

The use of the golden hamster in this study as the experimental animal has shed a different light on the accepted view of infantile stimulation research. The fact that this species represents an organism that is a hibernator, adapted to desert living and possessing a 'wild-type' of adrenal physiology sets it apart from the rat and the mouse. In addition, there is the reversal in the sexual dimorphism coupled with the differences in social and behavioural organisation and the suggestion that several physiological systems operate via different specific pathways or with different metabolites. This species therefore offers the possibilities of investigating other variables within the study of early experience than available using the rat (the most commonly used species) whilst still adhering relatively closely to the original experimental technique, particularly with regard to the temporal patterning of the procedure. The golden hamster is an easily maintained animal and, in the experience of this worker, tractable under experimental conditions. It should therefore be possible to determine more closely mediators in this field - although the final outcome of any specific activation may vary with species - and so determine any general applicability of the techniques.

REFERENCES

ADAM, J.H. (1975) The effect of embryonic stimulation on behaviour development in the chick. EXPTL. BRAIN RES. 23 (Suppl.): Abs. 4.

ADER, R. (1959) The Effects of Early Experience on Subsequent Emotionality and Resistance to Stress. PSYCHOLOGICAL MON. 73 (2) Abs. 472.

ADER, R. (1966) Frequency of stimulation during early life and subsequent emotionality in the rat. PSYCHOLOGICAL REP. 18 : 695-701.

ADER, R. (1969) Adrenocortical function & the measurement of "emotionality". ANYS 159 : 791-805.

ADLER, S. (1948) Origin of the golden hamster (Cricetus auratus) as a laboratory animal. NATURE 162 : 256-257.

AHROON, J.K. (1979) Does the male gerbil parent (Meriones Unguiculatas) contribute to pup mortality? A Reply. AN. BHVR. 27 (1) : 311-312.

AITKEN, P.P. (1974) Early experience, emotionality & exploration in the rat: A critique of Whimbey & Denenberg's hypothesis. DEVEL. PSYCHOBIOL. 7 (2) : 129-134.

ALPERT, M. (1950) Observations on the histophysiology of the adrenal gland of the golden hamster. ENDOCRIN. 46 : 166-176.

ALTMAN, J. (1967) Organic foundations of animal behaviour. HOLT, RINEHART & WISE, Inc.

ALTMAN, J. & SUDARSHAN, K. (1975) Postnatal development of locomotion in the laboratory rat. AN. BHVR. 23 (4): 896-920

ALTMAN, J,; DAS, G.D. & ANDERSON, W.J. (1968) Effects of infantile handling on morphological development of the rat brain: An exploratory study. DEVEL. PSYCHOBIOL. 1 : 10-20.

AMBROSE, J.A. (Ed) (1969) Stimulation in Early Infancy LONDON & N.Y. : ADADEMIC PRESS.

ANDERSON, A. (1968) The effects of electroconvulsive seizures during pregnancy on behavioural development of the offspring. DISS. ABST. 29 (4-6) B : 2189.

ANDERSON, C.O. & MASON, W.A. (1974) Early experience & complexity of social organisation in groups of young rhesus monkeys (*Macaca mulatta*). JN. OF COMP. PHYSIOL. PSYCHOLOGY 87 (4) : 681-690

ANDERSON, C.O.; DENENBERG, V.H. & ZARROW, M.X. (1972) Effects of handling & social isolation upon the rabbit's behaviour. BHVR. 43 : 165-175.

ANTON, A.H. (1969) Effect of group size, sex & time on organ weights eatecholamines and behaviour in mice. PHYSIOL. BHVR. 4 : 483-487.

ANTON, B.S. & BENNETT, T.L. (1972) Role of tactual-kinaesthetic feedback in transfer of perceptual learning in the golden hamster. PSYCH. SCI. 28 (3) : 157-158.

ASCHOFF, J. & MEYER-LOHMANN, J. (1954) 24 hour periodicity in rodents in natural and artificial light change. Z TIERPSYCHOL. 11 : 476-484.

AUER, J. (1951) Postnatal cell differentiation in the hypothalamus of the hamster. JN. COMP. NEUR. 95 : 17-42.

AZMITIA, E.C., Jr. (1975) Suprachiasmatic nuclei in relation to the reciprocal homeostatic loop between adrenal cortical secretion and tryptophan hydroxylase. EXPTL. BRAIN RES. (Suppl.) 23 : Abs. 18.

BABBINI, M. & DAVIS, W.M. (1967) Active avoidance learning in hamsters. PSYCH. SCI. 9 (3) : 149-150

BALAZS, R.; LEWIS, P.D. & PATEL, A.J. (1975) Effect of undernutrition (UN) & thyroid deficiency (TX) on postnatal cell formation in the rat brain. EXPTL. BRAIN RES. (Suppl.) 23 : Abs. 24.

BARON, A.; ANTONITIS, J.J. & SCHELL, S.F. (1962) Effects of early restriction & facilitation of climbing on later climbing behaviour of mice. JN. OF COMP. PHYSIOL. PSYCHOLOGY 55 (5) : 808-812.

BARRETT, A.M. & STOCKHOLM, M.A. (1963) The effect of housing conditions and simple experimental procedures upon the corticosterone level in plasma of rats. JN. ENDOCRIN. 26 : 97-105.

BASSETT, J.R.; CAIRNCROSS, K.D. & KING, M.G. (1973) Parameters of novelty, shock predictability & response contingency in corticosterone release in the rat. PHYSIOL. BHVR. 10 : 901.

BEACH, F.A. & JAYNES, J. (1954) Effects of early experience upon the behaviour of animals. PSYCHOLOGICAL BULL. 51 (3) : 239-263.

BEKOFF, M. & FOX, M.W. (1972) Postnatal neural ontogeny : Environment-dependent and/or environment-expectant? DEVEL. PSYCHOBIOL. 5 (4) : 323-341.

BELL, R.W.; NITSCHKE, W,; GORRY, T.H. & ZACHMAN, T.A. (1971) Infantile stimulation & ultrasonic signalling : a possible mediator of early handling phenomena. DEVEL. PSYCHOBIOL. 4 : 181-191.

BELL, R.W.; NITSCHKE, W,; BELL, N.J. & ZACHMAN, T.A. (1974) Early experience, ultrasonic vocalisations and maternal responsiveness in rats. DEVEL. PSYCHOBIOL. 7 : 235-242.

BENEDICT, F.G. & PETRIK, J.M. (1930) Metabolism studies on the wild rat. AM. JN. OF PHYSIOL. 94 : 662-685.

BERG, R.A.; SHANIN, R.D. & HULL, E.M. (1975) Early isolation in the gerbil (*Meriones unguiculatus*) : Behavioural and physiological effects. PHYSIOL. PSYCHOLOGY 3 (1) : 35-38.

BERNSTEIN, L. (1952) A note on Christie's 'Experimental naïvete and experiental naivete'. PSYCHOLOGICAL BULL. 49 : 38-40.

BERLYNE, D.E. (1955) The arousal & satiation of perceptual curiosity in the rat. JN. COMP. PHYSIOL. PSYCHOLOGY 48 : 238-246.

BEVAN, W. & GRODSKY, M.A. (1958) Hoarding in hamsters with systematically controlled pretest experience. JN. COMP. PHYSIOL. PSYCHOLOGY 51 : 342-345.

BILLINGHAM, R.E. & SILVERS, W.K. (1963) Skin transplants & the hamster. SCI. AM. 208 : 118-127.

BINDRA, D. (1957) Comparative psychology. ANN. REV. PSYCHOLOGY 8 : 399-414

BIRKE, L.M. (1976) Changes in exploration and distractability during rodent oestrus cycle. (Paper presented at ASAB Conference, London) AN. BHVR. 23 : 509

BLISS, E.L. (Ed). (1962) Roots of behaviour. N.Y., HARPER

BOICE, R. (1973) Stone (1932) revisited: What does his finding of superior maze learning in half-wild rats mean? BULL. PSYCH. SOC. 2 (4) : 208-210

BOICE, R.; HUGHES, D. & COBB, C.J. (1969) Social dominance in gerbils & hamsters. PSYCH. SCI. 16 : 127-128.

BORER, K.T. (1974) Absence of weight regulation in exercising hamsters. PHYSIOL. BHVR. 12 (4) 589-597.

BOURNE, G.H. (1949) "The Mammalian Adrenal Gland" CLARENDON PRESS, OXFORD

BOWLAND, J.A. & WATERS, R.H. (1955) Mazelearning by the golden hamster & the albino rat. PSYCH. REP. 1 : 437-440

BOYER, C.C. (1953) Chronology of development for the hamster JOURNAL MORPH. 92 : 1-37

BRAIN, P.F. (1971) Effects of isolation on adrenocortical & gonadal function in male and female golden hamsters. JN. ENDOCRIN. 53 : lxii - lxiii

BRAIN, P.F. (1972) Effects of isolation/grouping on endocrine function and fighting behaviour in male and female golden hamsters (Mesocricetus auratus, Waterhouse). BHVRL. BIOL. 7 (3) : 349-357.

BRAIN, P.F. & EVANS, C.M. (1972) Some recent studies on the effects of corticotrophin on agnostic behaviour in the house mouse and the golden hamster. JN. ENDOCRIN. 57 : xxxix

BRAIN, P.F. & NOWELL, N.W. (1970a) Activity & defecation related to aggressiveness & adrenal stress response in adult male laboratory mice. PHYSIOL. BHVR. 5 (1) : 259-261

BRAIN, P.F. & NOWELL, N.W. (1970b) The effects of differential grouping on endocrine function of mature male albino mice. PHYSIOL. BHVR. 5 (8) : 907-910.

BRAUN, H.G. (1953) Abnormal sexual behaviour of the golden hamster under hormonal influence. Z.TIERPSYCHOL. 10 : 55-56.

BRITTON, S.W. (1930) Seasonal variations in survival after adrenalectomy. AM. JN. PHYSIOL. 94 : 686-691.

BROADHURST, P.L. (1957) Determinants of emotionality in the rat. I. Situational factors. BRIT. JN. OF PSYCHOLOGY 48 : 1-12.

BROADHURST, P.L. (1960) Experiments in psychogenetics : Applications of bio-metrical genetics to the inheritance of behaviour. In: Experiments in Personality, Vol. 1, Psychogenetics & psychopharmacology. (Edited by J.J. Eysenck) pp 3-102.

BRONSON, F.H. (1962) Behavioural & physiological correlates of density and subordination. In: 59th Annual Meeting of the American Society of Zoologists, Philadelphia.

BRONSTEIN, P.M.; NEIMAN, H.; WOLKOFF, F.D. & LEVINE, M.J. (1974) The development of habituation in the rat. AN. LEARN. BHVR. 2 (2) : 92-96.

BRUCE, H. (1970) Pheromones. BRIT. MED. JN. 26 : 10-13

BRUCE, H.M. & HINDLE, E. (1934) The golden hamster, Cricetus (Mesocricetus) auratus Waterhouse. Notes on its breeding & growth. PROC. ZOOL. SOC. LOND. : 361-366 (Vol. 1).

BRUINVELS, J. (1975) Regulation of the uptake of monoamines and their amino acid precursors by sodium & potassium. EXPTL. BRAIN RES. (Suppl.) 23 : Abs. 55.

BUCHANAN, A.R. & HILL, R.M. (1949) Myelination of the hypothalamus & its relation to thermoregulation in the hamster. PROC. SOC. EXP. BIOL. MED. 71 : 126-129.

BUTLER, R.G. (1980) Population size, social behaviour & dispersal in house mice : a quantitative investigation. AN. BHVR. 28 (1) : 78-85.

CALEY, D.W. & MAXWELL, D.S. (1968) An electron microscopic study of neuroglia during postnatal development of rat cerebellum. JN. COMP. NEUR. 133 : 45-70.

CALHOUN, J.B. (1962) 'The ecology & sociology of the norway rat'. BETHESDA : H.E.W. Public Health Service.

CALLISON, D.A.; HIMWICH, W.A. & TURNER, J.K. (1973) Postnatal development of the electrocortical activity in the golden hamster (Mesocricetus auratus). DEVEL. PSYCHOBIOL. 6 (5) : 411-420.

CAMPBELL, B.A. & MABRY, P.D. (1972) Ontogeny of behavioural arousal : A comparative study. JN. OF COMP. PHYSIOL. PSYCHOLOGY 81 (3) : 371-379.

CAMPBELL, B.A.; MISANIN, J.R.; WHITE, B.C. & LYTLE, L.D. (1974) Species differences in ontogeny of memory: Indirect support for neural maturation as a determinant of forgetting. JN. COMP. PHYSIOL. PSYCHOLOGY <u>87</u> (2) : 193-202.

CANDLAND, D.K. & CAMPBELL, B.A. (1962) Development of fear in the rat as measured by behaviour in the open-field. JN. COMP. PHYSIOL. PSYCHOLOGY <u>55</u> (4) : 593-596.

CANNON, W.B. (1929) Bodily changes in pain, hunger, fear and rage. NEW YORK : APPLETON.

CASTELLANO, C. & OLIVERIO, A. (1976) Early malnutrition & postnatal changes in brain and behaviour in the mouse. BRAIN RES. 101 (2) : 317-325.

CHAFFEE, R.R.J. (1966) On experimental selection for super-hibernating and non-hibernating lines of Syrian hamsters. JN. THEOR. BIOL. <u>12</u> : 151-154.

CHATFIELD, P.O. & LYMAN, C.P. (1950) Circulatory changes during process of arousal in the hibernating hamster. AM. JN. PHYSIOL. <u>163</u> : 566-574.

CHESTER JONES, I. (1955) Role of the adrenal cortex in reproduction. BRIT. MED. BULL. <u>11</u> : 156-160.

CHESTERMAN (1962) Paper presented at 8th INT. CANCER CONG., MOSCOW, p. 486 cited by Hoffman et al, 1968 (q.v.).

CHEVILLARD, L.; PORTET, R. & CADOT, M. (1963) Growth rate of rats born and reared at 5°C and 30°C. FED. PROC. <u>22</u> : 699-703.

CIOFFI, L.A.; DE LUCA, B.; SADILE, A.G. & DI BENEDETTA, C. (1975) Nutritional effects on the development of brain glycoproteins. EXPTL. BRAIN RES. (Suppl.) 23 : Abs. 73.

CLARK, M.M. & BENNETT, G.G. (1977) The role of the physical rearing environment in the domestication of the mongolian gerbil (*Meriones unguiculates*). AN. BHVR. 25 (2) : 298-316.

COOPER, R.M. & ZUBECK, J.P. (1958) Effects of enriched & restricted early environments on the learning ability of bright and dull rats. CAN. JN. OF PSYCHOLOGY 12 : 159-164.

CORNER, M.A. & RICHTER, A.P. (1975) Development of dendrites & synapses in embryonic chick cerebral neurons. EXPTL. BRAIN RES. (Suppl.) 23 : Abs. 83.

CRAIN, S.M. (1952) Development of electrical activity in the cerebral cortex of the albino rat. PROC. SOC. EXP. BIOL. MED. 81 : 49-51.

DALY, J.M. (1971) Behavioural development, early experience and maternal behaviour in the golden hamster (*Mesocricetus auratus*). Unpublished Doctoral Thesis, University of Toronto, Toronto, Canada.

DALY, M. (1973) Early stimulation of rodents: A critical review of present interpretations. BR. JN. PSYCHOLOGY 64 (3) : 435-460.

DALY, M. (1976) Behavioural development in 3 hamster species. DEVEL. PSYCHOBIOL. 9 (4) : 315-323.

DEANE, H.W. & LYMAN, C.P. (1954) Body temperature, thyroid and adrenal cortex of hamsters during cold exposure and hibernation, with comparisons to rats. ENDOCRIN. 55 : 300-315.

DEETS, A.C. (1974a) Age-mate or twin sibling : effects on monkey age-mate interactions during infancy. DEVEL. PSYCHOLOGY 10 (6) : 913-928.

DEETS, A.C. (1974b) Age-mate or twin sibling : effects on interactions between mother monkeys & infants. DEVEL. PSYCHOLOGY 10 (5) : 748-763.

DELUSI (1973) Paper presented at ASAB Conference, 1973 (London).

DENENBERG, V.H. (1959) The interactive effects of infantile & adult shock levels upon learning. PSYCHOLOGICAL REP. 5 : 357-364.

DENENBERG, V.H. (1962a) An attempt to isolate critical periods of development in the rat. JN. COMP. PHYSIOL. PSYCHOLOGY 55 : 813-815.

DENENBERG, V.H. (1962b) The effects of early experience. In: The Behaviour of Domestic Animals (Edited by Hafez, E.S.E.) pp 109-138.

DENENBERG, V.H. (1963) Early experience and emotional development. SCI. AM. 208 (6) : 138-146.

DENENBERG, V.H. (1964) Critical periods, stimulus input & emotional reactivity : A theory of infantile stimulation. PSYCHOLOGICAL REV. 71 : 335-351

DENENBERG, V.H. (1967) Stimulation in infancy, emotional reactivity and exploratory behaviour. In: Neurophysiology and Emotion (Edited by Glass, D.C.) pp 161-190.

DENENBERG, V.H. (1968) A consideration of the usefulness of the critical period hypothesis as applied to the stimulation of rodents in infancy. In: Newton & Levine (q.v.) pp 142-167 Ch. VI

DENENBERG, V.H. (1969) Open-field behaviour in the rat: What does it mean? ANN. N.Y. ACAD. SCI. 159: 852-859.

DENENBERG, V.H. (1969) Experimental programming of life histories in the rat. In: "Stimulation in Early Infancy" (Edited by Ambrose, A.) Acad. Press: London, N.Y. p. 21.

DENENBERG, V.H. (ed). (1972) The development of behaviour (Sinauer Associates Inc.: Stamford, Conn.).

DENENBERG, V.H. & BELL, R.W. (1960) Critical periods for the effects of infantile experience on adult learning. SCI. 131 : 227-228.

DENENBERG, V.H.; MORTON, J.R.C.; KLINE, N.J. & GROTA, L.J. (1962) Effects of duration of infantile stimulation upon emotionality. CAN. JN. PSYCHOLOGY 16 : 72-76.

DENENBERG, V.H. & HALTMEYER, G.C. (1967) Test of the monotonicity hypothesis concerning infantile stimulation and emotional reactivity. JN. COMP. PHYSIOL. PSYCHOLOGY 63 : 394-396.

DENENBERG, V.H. & MORTON, J.R.C. (1962) Effects of environmental complexity and social groupings upon the modification of emotional behaviour. JN. COMP. PHYSIOL. PSYCHOLOGY 55 : 242-246.

DENENBERG, V.H. & MORTON, J.R.C. (1964) Infantile stimulation, prepubertal sexual-social interaction and emotionality. AN. BHVR. 12 : 11-13.

DENENBERG, V.H.; BRUMHAGHIM, J.T.; HALTMEYER, G.C. & ZARROW, M.X. (1967) Increased adrenocortical activity in the neonatal rat following handling. ENDOCRIN. 81 : 1047-1052.

DENENBERG, V.H. & SMITH, S.A. (1963) Effects of infantile stimulation and age upon behaviour. JN. COMP. PHYSIOL. PSYCHOL. 56 : 307-312.

DENENBERG, V.H.; WOODCOCK, J.M. & ROSENBERG, K.M. (1968) Long-term effects of preweaning and postweaning free-environment experience on rats problem-solving behaviour. JN. COMP. PHYSIOL. PSYCHOLOGY 66: 533-535.

DENENBERG, V.H. & ZARROW, M.X. (1971) Effects of handling in infancy upon adult behaviour and adrenocortical activity: Suggestions for a neuroendocrine mechanism. In: Walcher, D.H. & Peters, D.L. (Eds.) pp. 39-64 (q.v.)

DENENBERG, V.H.; WYLY, M.V.; BURNS, J.K. & ZARROW, M.X. (1973) Behavioural effects of handling rabbits in infancy. PHYSIOL. BHVR. 10 : 1001-1004.

DENYES, A. & HORWOOD, R.H. (1960) A comparison of free adrenal cortical steroids in the blood of a hibernating & non-hibernating mammal. CAN. JN. BIOCHEM. PHYSIOL. 38 : 1479.

DESSI-FULGHERI, F.; LUPO, C. & VALERI, P. (1975) Uptake of corticosterone by the brain of rats reared under different conditions. EXPTL. BRAIN RES. (Suppl.) 23 : Abs. 448.

DEUTSCH, J. & LARSSON, K. (1974) Model-oriented sexual behaviour in surrogate-reared rhesus monkeys. BRAIN, BHVR. & EVOLUTION 19 (3) : 157-164.

DEVOR, M. & MURPHY, M.R. (1973) The effect of peripheral olfactory blockade on the social behaviour of the male golden hamster. BHVRL. BIOL. 9 (1) : 31-42.

DE WIED, D. & WEIJNEN, J.A.W.M. (Ed) (1970) Progress in brain research : Vol. 32 : PITUITORY, ADRENAL & THE BRAIN. AMSTERDAM, ELSEVIER.

DE WIED, D.; WITTER, A. & GREVEN, H.M. (1975) Behaviourally active ACTH analogues. EXPTL. BRAIN RES. (Suppl.) 23 : Abs. 99.

DEZA. L. & EIDELBERG, E. (1967) Development of cortical electrical activity in the rat. EXP. NEUROL. 17 : 425-438.

DIETERLEN, F. (1959) Behaviour of golden hamster; investigations of its development and hereditary factors using olfactory isolation during rearing. Z. TIERPSYCHOL. 16: 47-103.

DILGER, W.C. (1962) The behaviour of lovebirds. SCI. AM. 206: 88-98.

DILL, D.B.; ADOLPH. E.F. & WILBER, C.G. (Eds.) (1964) "Handbook of Physiology, Section 4 : Adaptation to the environment. WILLIAMS & WILKINS COMP., BALTIMORE.

DOBBING, J. & SMART, J.L. (1974) Vulnerability of developing brain and behaviour. BR. MED. BULL. 30 (2) : 164-168.

DRICKAMER, L.C. & VANDENBERGH, J.G. (1973a) Predictors of social dominance in the adult female golden hamster. (*Mesocricetus auratus*). AN. BHVR. 21 : 564-570.

DRICKAMER, L.C.; VANDENBERGH, J.G. & COLBY, D.R. (1973b) Predictors of dominance in the male golden hamster. (*Mesocricetus auratus*). AN. BHVR. 21 : 557-563.

D'SOUZA, F. & MARTIN, R.D. (1974) Maternal behaviour & effects of stress in tree shrews. NATURE 251 : 309

DUDLEY, D. (1974) Contributions of paternal care to the growth and development of the young in *Peromyscus californicus*. BHVRL. BIOL. 11 : 155-166.

DURUP, H. (1965) Influence of the odorous traces left by the hamster at the time of the learning of an olfactory discrimination maze. PSYCHOLOGICAL ABSTS. 39 (5-6) ABS. 9683.

EAYRS. J.T. & GOODHEAD, B. (1959) Postnatal development of the cerebral cortex in the rat. JN. ANAT. 93 : 385-402.

EDENS, F.W. & SIEGEL, H.S (1975) "Adrenal responses in high and low ACTH response lines of chickens during acute heat stress". GEN. COMP. ENDOCRIN. 25 (1) : 64-73.

EDWARD, H.P.; BARRY, W.F. & WYSPIAŃSKI, J.O. (1968) Early environment effects on rat photic evoked potentials: A preliminary study. REVISTA INTERAMERICANA DE PSICOLOGIA 2 : 85-92.

EIBL-EIBESFELD, I. (1953) Zur Ethologie des hamsters (*Cricetus cricetus* L.) ZEIT. TIERPSYCHOL. 10 : 204-254.

ELIAS, J.W. & BELL, R.W. (1975) Open-field interpretation: Social status & social .v. spatial stimulation as factors. JN. GEN. PSYCHOLOGY 92 (2) : 293-4.

ELLERMAN, J.R. (1941) The families and genera of living rodents: Vol. 2. Family Muridae. (BRITISH MUSEUM, NATURAL HISTORY).

ELLERMAN, J.R. (1949) The families and genera of living rodents: Vol. 3. (BRITISH MUSEUM, NATURAL HISTORY).

ELTON, R.L.; ZARROW, I.G. & ZARROW, M.X. (1959) Depletion of A.A.A. & cholesterol: A comparative study. ENDOCRIN. 65 : 152-157.

ELWOOD, R.W. (1975) Paternal & maternal behaviour of the Mongolian gerbil and the development of the young. UNPUBLISHED PhD THESIS, UNIVERSITY OF READING.

ELWOOD, R.W. (1977) Changes in the responses of male and female gerbils (Meriones unquiculatus) towards test pups during the pregnancy of the female. AN. BHVR. 25 (1) : 46-51.

ELWOOD, R.W. & BROOM, D.M. (1978) The influence of litter size and parental behaviour of the development of Mongolian gerbil pups. AN. BHVR. 26 (2) : 438-454.

EMERY, F.E. & GRECO, P.A. (1940) The comparative activity of desoxycorticosterone acetate and progesterone in adrenalectomised rats. ENDOCRIN. 27 : 473-476

ENDROCZI, E. & NYAKAS, C. (1975) Pituitary - adrenal function, brain monamines and behaviour. EXPTL. BRAIN RES. (Suppl.) 23 Abst. 129.

ESSMAN, W.B. (1971) Isolation-induced behavioural modification: Some neurochemical correlates. In: STERMAN et al (1971) Ch. 14, pp 265-276.

EVANS, C.M. & BRAIN, P.F. (1974) Some studies on endocrine influences on aggressive behaviour in the golden hamster (Mesocricetus auratus, Waterhouse). In: SWAAB, D. F. & SCHADE, J.P. (q.v.)

EWER, R.F. (1967) The behaviour of the African giant rat (Cricetomys gambianus, Waterhouse). Z. TIERPSYCHOL. 24 : 6-79.

EYSENCK, J.J. (Ed.) (1960) Experiments in Personality, Vol. 1; Psychogenetics & psychopharmacology. LONDON : ROUTLEDGE & KEGAN PAUL.

FARRIS, E.J. (Ed.) (1950) The care and breeding of laboratory animals. JOHN WILEY & SONS, INC. (NY).

FEIGLEY, D.A. (1974) Effects of scopolamine on activity and passive avoidance learning in rats of different ages. JN. COMP. PHYSIOL. PSYCHOLOGY 87 (1) : 26-36.

FERCHMIN, P.A.; BENNETT, E.L. & ROSENZWEIG, MR. (1975) Direct contact with enriched environment is required to alter cerebral weights in rats. JN. COMP. PHYSIOL. PSYCHOLOGY 88 (1) : 360-367

FIALA, B.; SNOW, F.M. & GREENOUGH, W.T. (1977) "Impoverished" rats weigh more than "enriched" rats because they eat more. DEVEL. PSYCHOBIOL. 10 (6) : 537-541.

FIELDS, P.E. (1953) The efficiency of the serial multiple visual discrimination apparatus & method with white rats. JN. COMP. PHYSIOL. PSYCHOLOGY 46 : 69-76.

FISKE, V.M. & LAMBERT, H.H. (1962) Effect of light on the weight of the adrenal in the rat. ENDOCRIN. 71 : 667-668

FITTINGHOFF, N.A.; LINDBURG, D.G.; GOMBER, J. & MITCHELL, G. (1974) Consistency & variability in the behaviour of mature, isolation-reared, male rhesus macaques. PRIMATES 15 (2-3) : 111-139

FORD, D.H. (Ed.) (1973) Progress in Brain Research, Vol. 40 Neurobiological Aspects of Maturation and Aging. ELSEVIER SCIENTIFIC PUBLISHING COMPANY, AMSTERDAM: LONDON; NEW YORK.

FORGAYS, D.G. & FORGAYS, J.W. (1952) The nature of the effect of free-environmental experience in the rat. JN. COMP. PHYSIOL. PSYCHOLOGY 45 : 322-328.

FORGAYS, D.G. & READ, J.M. (1962) Crucial periods for free-environmental experience in the rat. JN. COMP. PHYSIOL. PSYCHOLOGY 55 : 816-818.

FORTNER, J.G. (1958) Etiologic implications for spontaneous carcinogenesis in syrian hamster. PROC. 7th INT. CANCER CONG. 254

FORTNER. J.G. & SCHRODT, G.R. (1961) Transplantable tumours of the Syrian golden hamster. Part I: Tumours of the alimentary tract, endocrine glands & melanomas. CANCER RES. 21 (6 part 2) : 161 (Suppl.)

FOX, M.W. (Ed.) (1968) Abnormal behaviour in animals. W.B. Saunders Co: Philadelphia.

FREY, R.B. (1966) Behavioural patterns in spatially restricted population hamsters. DISS. ABSTRACT 27 (6-B) : 2159

GALLUP, G.G. & SUAREZ, S.D. (1980) An ethological analysis of open-field behaviour in chickens. AN. BHVR. 28 (2) : 368-378.

GANDELMAN, R,; PASCHKE, R.E.; ZARROW, M.X. & DENENBERG, V.H. (1970) Care of young under communal conditions in the mouse (Mus musculus) DEVEL. PSYCHOBIOL. 3 (4) : 245-250.

GARDENER, E.B.; BOITANO, J.J.; MANCINO, N.S.; D'AMICO, D.P. & GARDNER, E.L. (1975) Early environment : rats male. Environmental enrichment & deprivation: effects on learning, memory & exploration. PHYSIOL. BHVR. 14 (3): 321-327

GASKIN, J.H. & KITAY, J.I. (1970) Adrenocortical function in the hamster: sex differences and effects of gonadal hormones. ENDOCRIN. 87 : 779-786

GASKIN, J.H. & KITAY, J.I. (1971) Hypothalamic & pituitary regulation of adrenocortical function in the hamster: effects of gonadectomy and gonadal hormone ENDOCRIN. 89 : 1047-1053

GELLER, E. (1971) "Some observations on the effects of environmental complexity & isolation on biochemical ontogeny". In: STERMAN et al (1971), Ch. 15, pp 277-296

GERLING, S. & YAHR, P. (1979) Effect of the male parent on pup survival in mongolian gerbils (Meriones unguiculatus) AN. BHVR. 27 (1) : 310-311.

GERRITZ, E.K. (1971) Social behaviour of pairs of male rodents in the open-field and the effects of social isolation. DISS. ABSTS. 31 (9-A) : 4886

GIBSON, E.J. & WALK, R.D. (1956) The effect of prolonged exposure to visually presented patterns on learning. JN. COMP. PHYSIOL. PSYCHOLOGY 49 : 239-242.

GIBSON, E.J.; WALK, R.D.; & TIGHE, T.J. (1959) Enhancement & deprivation of visual stimulation during rearing as factors in visual discrimination learning. JN. COMP. PHYSIOL. PSYCHOLOGY 52 : 74-81.

GILBERT, F.F. & BAILEY, E.D. (1969) Visual isolation and stress in female ranch mink particularly during the reproductive season. CAN. J. ZOOL. 47 : 209-212

GINSBURG, B.E. (1960) Genetic control of the ontogeny of stress behaviour. Paper read at the annual meeting AMERICAN PSYCHOLOGICAL ASSOC., CHICAGO, Sept. 1960.

GOLDMAN, B.D. & SHERIDAN, P.J. (1974) The ovulatory surge of gonadotrophin & sexual receptivity in the female golden hamster. PHYSIOL. BHVR. 12 (6) : 991-995.

GOLDMAN, L. & SWANSON, H.H. (1975) Developmental changes in pre-adult behaviour in confined colonies of golden hamsters. DEVEL. PSYCHOBIOL. 8 (2) : 137-150.

GOODMAN, E.D. & FIRESTONE, M.I. (1973) Olfactory bulb lesions: Nest reinforcement & handling reactivity in hamsters. PHYSIOL. BHVR. 10 (1) : 1-8.

GRAMSBERGEN, A. (1975) Neuro-ontogeny of behavioural states in the undernourished rat. EXPTL. BRAIN RES. (Suppl.) 23 : Absts. 152.

GRANT, E.C. & MACKINTOSH, J.H. (1963) A comparison of the social postures of some common laboratory rodents. BHVR. 21 (3-4) : 246-259.

GRANT, E.C.; MACKINTOSH, J.H. & LERWILL, C.J. (1970) The effect of a visual stimulus on the agonistic behaviour of the golden hamster. Z. TIERPSYCHOL. 27 (1) : 73-77.

GRAVES, A.T. (1945) Development of the golden hamster, *Cricetus auratus* Waterhouse, during the first nine days. AM. JN. ANAT. 77 (2) : 219-244.

GREEP, R.O. & DEANE, H.W. (1949) The cytology & cytochemistry of the adrenal cortex. ANNALS N.Y. ACAD. SCI. 50 (6) : 596-615.

GREGORY, E. (1975) "A hamster is not a rat......." DEVEL. PSYCHOBIOL. 8 (6) : 573.

GRIFFITHS, W.J. & STRINGER, W.F. (1952) The effects of intense stimulation experienced during infancy on adult behaviour in the rat. JN. COMP. PHYSIOL. PSYCHOLOGY 45 : 301-306.

GROTA, L.J. (1975) Effects of early experience & dexamethasone adrenocortical reactivity. DEVEL. PSYCHOBIOL. 8 (3) : 251-259.

GROTA, L.J. (1976) Effects of early experience on the metabolism and production of corticosterone in rats. DEVEL. PSYCHOBIOL. 9 (3) : 211-215.

GUMMA, M.R. & SOUTH, F.E. (1970) Hypothermia and behavioural thermoregulation by the hamster (Mesocricetus auratus) AN. BHVR. 18 (3) : 504-511.

GUMMA, M.R.; SOUTH, F.E. & ALLEN, J.N. (1967) Temperature preference in golden hamsters. AN. BHVR. 15 : 534-537.

HAFEZ, E.S.E. (Ed.) (1962) The behaviour of domestic animals. LONDON: BAILLIERE, TINDALL & COX

HAGGETT, B.N. & WERBOFF, J. (1968) Temperature reduction in neonatal mice: effects on later behaviour. DEVEL. PSYCHOBIOL. 1 : 257-265.

HALL, C.S. (1934) Emotional behaviour in the rat: I.Defecation and urination as measures of individual differences in emotionality. JN. COMP. PSYCHOLOGY 18 : 385-403

HALL, C.S. & WHITEMAN, P.H. (1951) The effects of infantile stimulation upon later emotional stability in the mouse. JN. COMP. PHYSIOL. PSYCHOLOGY 44 : 61-66

HALL, K. (1940) Changes in the adrenals of gonadectomised male and female rats produced by prolonged injections of sex hormones. J. PATH. & BACT. 51 : 75-82

HALTMEYER, G.C.; DENENBERG, V.H.; THATCHER, J. & ZARROW, M.X. (1966) Response of the adrenal cortex of the neonatal rat after subjection to stress. NATURE 212 : 1371-1373

HANNEY, P.W. (1975) "Rodents: their lives and habits". DOUGLAS DAVID & CHARLES LTD., CANADA.

HAYWARD, J.S. (1965) Microclimate temperature and its adaptive significance to six geographic races of Peromyscus. CAN. JN. ZOOL. 43 : 341-350

HEBB, D.O. (1949) "The organisation of behaviour" WILEY, NEW YORK.

HELDMAIER, G. & HOFFMAN, K. (1974) Melatonin stimulates growth of brown adipose tissue. NATURE 247 : 224-225.

HENDERSON, N.D. (1964) Behavioural effects of manipulation during different stages in the development of mice. JN. COMP. PHYSIOL. PSYCHOLOGY 57 : 284-289.

HENDERSON, N.D. (1967) Early shock effects in the BALB/C mouse. JN. COMP. PHYSIOL. PSYCHOLOGY 64 : 168-170.

HENDERSON, N.D. (1969) Prior-treatment effects on open-field emotionality; the need for representative design. ANN. N.Y. ACAD. SCI. 159: 860-868.

HENRY, J.P.; STEPHENS, P.M. & WATSON, F.M. (1975) Force breeding, social disorder and mammary tumour formation in CBA/USC mouse colonies: A pilot study. PSYCHOSOMATIC MED. 37 (3) : 277-283.

HESS, J.L.; DENENBERG, V.H.; ZARROW, M.X. and PFEIFER, W.D. (1969) Modification of the corticosterone response curve as a function of handling in infancy. PHYSIOL. BEHAVIOUR 4 : 109-111.

HILLMAN, J.R. & SELIGER, W.G. (1975) Histochemistry & ultrastructure of adrenal cortical development in the golden hamster. GEN. COMP. ENDOCRIN. 25 : 14-24.

HIMWICH, W.A. (1973) "Problems in interpreting neurochemical changes occurring in developing and aging animals". In: Progress in Brain Research: D.H. Ford (Ed.) Ch. 2 pp 13-23.

HISSA, R. & LAGERSPETZ, K. (1964) The postnatal development of homoithermy in the golden hamster. ANN. MED. EXP. FENN. 42 : 43-45.

HOFER, M.A. (1975) Survival & recovery of physiologic functions after early maternal separation in rats. PHYSIOL. BEHAVIOUR 15 (4) : 475-480.

HOFFMAN, R.A. (1964) "Terrestrial animals in cold; hibernators". In: Dill et al (Eds.) (1964) Ch. 24, p. 379.

HOFFMAN, R.A. & REITER, R.J. (1965) Pineal gland: Influence on gonads of male hamsters. SCIENCE 148 : 1609-1611.

HOFFMAN, R.A.; HESTER, R.J. & TOWNS, C. (1965) Effect of light and temperature on the endocrine system of the golden hamster (*Mesocricetus auratus*, Waterhouse). COMP. BIOCHEM. PHYSIOL. 15 : 525-533.

HOFFMAN, R.A.; ROBINSON, P.F. & MAGALHAES, H. (1968) "The golden hamster: its biology and use in medical research". AMES: THE IOWA UNIVERSITY PRESS.

HOLMES, W.N. (1955a) Variations in adrenal ascorbic acid concentration of the hamster during the pre-hibernatory period. ENDOCRIN. 57 : 409-413.

HOLMES, W.N. (1955b) Histological variations in the adrenal cortex of the golden hamster with special reference to the X-zone. ANAT. REC. 122 (3) : 271-294.

HOWARD, E.; OLTON, D.S. & JOHNSON, C.T. (1976) Active avoidance and brain DNA after postnatal food deprivation in rats. DEVEL. PSYCHOBIOL. 9 (3) : 217-221.

HOWARD, W.E. (1959) Survival of hamsters on Californian Rangeland. JN. MAMMALOGY 40 (4) : 613.

HUBSCHER, U.; KNUSEL, A.; HEIDELBERGER, R. & KUENZLE, C.C. (1975) DNA polymerases in brain neuronal nuclei; increased activity in rats required to perform a complex behavioural task. EXPTL. BRAIN RES. (Suppl.) 23 : Absts. 224.

HUCKLEBRIDGE, F.H. & NOWELL, N.W. (1974) Plasma catecholamine response to physical & psychological aspects of fighting in mice. PHYSIOL. BHVR. 13 (1) : 35-40.

HUGHES, C.W. (1975) Early experience in domestication. JN. COMP. PHYSIOL. PSYCHOLOGY 88 (1) : 407-417.

HUGHES, R.N. (1969) Exploration in three laboratory rodents. PERCEPTUAL & MOTOR SKILLS 28 (1) : 90.

HUSSEY, F.A. (1971) Avoidance learning in the golden hamster: the effect of CS-US interval. PSYCH. SCI. 23 (1-A) : 5-7.

HUTCHINGS, D.E. (1963) Early 'experience' and its effects on later behavioural processes in rats. III Effects of infantile handling and body temperature reduction on later emotionality. TRANS. N.Y. ACAD. SCI. 25 : 890-901.

HUTCHINGS, D.E. (1967) Infantile body temperature loss in rats: effects of duration of cold exposure, rate of heat loss, level of hypothermia, and rewarming on later emotionality. PSYCHOLOGICAL REP. 21 : 985-1002.

HUTCHINSON, J.B. (Ed.) (1978) "Biological determinants of sexual behaviour". JOHN WILEY & SONS.

INGLIS, I.R. (1975) Enriched sensory experience in adulthood increases subsequent exploratory behaviour in the rat. AN. BHVR. 23 (4) : 932-939.

ISAACSON, J.E. Jr. (1949) Induction of psychic oestrus in the hamster with desoxycorticosterone acetate and its effects on the epithelium of the lower reproductive tract. ENDOCRIN. 45 : 558-563.

JACOBSON, S. (1963) Sequence of myelinisation in the brain of the albino rat. A.Cerebral cortex, thalamus and related structures. JN. COMP. NEUR. 121 (1) : 5-29

JARRARD, L.E. & BUNNELL, B.N. (1968) Open-field behaviour of hippocampal lesioned rats & hamsters. JN. COMP. PHYSIOL. PSYCHOLOGY 66 (2) : 500-502.

JELINEK, V. (1971) "The influence of the condition of the laboratory animals employed on the experimental results". In: "Defining the laboratory animal". Int. Committee on laboratory animals (IV Symposium), pp 113-118; publ. : National Academy of Sciences, Washington, D.C.

JOHNSON, J.I.; GOY, R.W. & MICHELS, K.M. (1962) Physiological mechanisms & behaviour patterns. In: Hafez, E.S.E. (Ed.), Ch. 7; pp 139-179 (q.v.).

JOHNSON, R. (1974) The use of space in caged golden hamsters. ZEIT. FÜR TIER. 35 (2) : 124-131.

JOHNSON, W.A. (1974) Sex hormones & hamster copulation. DISS. ABST. INT. 35 (2-B) : 1080

JOHNSON, W.A. (1975) Neonatal androgenic stimulation and adult sexual behaviour in female and male golden hamsters. JN. COMP. PHYSIOL. PSYCHOLOGY 89 (5) : 433-441.

JOHNSTON, R.E.; MIYA, T.S. & PAOLINO, R.M. (1974) Facilitated avoidance learning and stress-induced corticosterone levels as a function of age in rats. PHYSIOL. BHVR. 12 (2) : 305-308.

JOHNSTON, R.E. & LEE, N.A. (1976) Persistence of the odour deposited by two functionally distinct scent marking behaviours of golden hamsters. BHVRL. BIOL. 16 (2) : 199-210.

JOHNSTON, R.E. (1977) The causation of two scent marking behaviour patterns in female hamsters (Mesocricetus auratus) AN. BHVR. 25 (2) : 317-327.

JOHNSTON, W.H. (1964) The effects of environmental size, complexity and confinement on temporal trends of escape and exploration. DISSERTATION ABSTRACTS 25 (3) : 2067-8

JOLLEY, A. & DREESMAN, H. (1973) Increased illumination level during gestation and offspring emotionality in the rat. AN. BHVR. 21 : 660-664.

JOSIMOVICH, J.B.; LADMAN, A.J. & DEANE, H.W. (1954) A histophysiological study of the developing adrenal cortex of the rat during fetal and early postnatal stages. ENDOCRIN. 54 : 627-639

KAYSER, C. (1946) An attempt to analyse the mechanism of sleep in hibernation. PSYCHOLOGICAL ABSTS. : 3112.

KEELER, C.E. (1947) Coat colour, physique & temperament. JN. HERED. 38 : 271

KEYES, P.H. (1949) Adreno-cortical changes in syrian hamsters following gonadectomy. ENDOCRIN. 44 : 274-281.

KING, D.L. (1969) The effect of early experience and litter on same weight and maturational variables. DEVEL. PSYCHOBIOL. 1 : 576-584.

KING, J.A. (1958) Parameters relevant to determining the effect of early experience upon the adult behaviour of animals. PSYCHOLOGICAL BULL. 55 : 46-58.

KING, J.A. (1968) 'Species specificity and early experience'. In: Newton & Levine (Eds.), Ch. 2, pp 42-64, (q.v.).

KING, J.A. & ELEFTHERIOU, B.E. (1959) Effects of early handling upon adult behaviour in two subspecies of deermice, Peromyscus maniculatus. JN. COMP. PHYSIOL. PSYCHOLOGY 52 : 82-88.

KIRBY, A.C. (1963) Summer-winter variations in, and effect of photoperiod on, pituitary prolactin: hamsters. (Masters thesis, LOUISIANA STATE UNIVERSITY, BATON ROUGE).

KITAY, J.I.; COYNE, M.D.; NEWSOM, W. & NELSON, R. (1965) Relation of the ovary to adrenal corticosterone production and adrenal enzyme activity in the rat. ENDOCRIN. 77 : 902-908.

KOBAYASHI, T.; INMAN, O.; BUNO, W. & HIMWICH, H.E. (1963) A multidisciplinary study of changes in mouse brain with age. In: J. Wortis (Ed.) Recent advances in Biol. Psychiatry; Vol. 5; Plenum : NY. pp 293-308.

KOLB, B. & NONNEMAN, A.J. (1975) The development of social responsiveness in kittens. AN. BHVR. 23 (2) : 368-374.

KONEFF, A.A.; SIMPSON, M.E. & EVANS, H.M. (1946) Effects of chronic administration of diethylstilbestrol on pituitary and other endocrine organs of hamster. ANAT. REC. 94 : 169-196.

KREHBIEL, R.H. (1952) Mating of the golden hamster during pregnancy. ANAT. REC. 113 (1) : 117-121.

LABARBA, R.C.; FERNANDEZ, B.; WHITE, J.L. & STEWART, A. (1974) The effects of neonatal tactile stimulation on adult emotional reactivity in BALB/C mice. DEVEL. PSYCHOBIOL. 7 (5) : 393-398.

LANDAUER, M.R.; BANKS, E.M. & CARTER, C.S. (1978) Sexual & olfactory preferences of naive & experienced male hamsters. AN. BHVR. 26 (2) : 611-621.

LANDAUER, T.E. & WHITING, J.W.M. (1964) Infantile stimulation and adult stature of human males. AM. ANTHROPOLOGIST 66 (6) : 1007-1028.

LAWLOR, M.M. (1956) Hereditary determinants of social dominance in the golden hamster. BRIT. JN. AN. BHVR. 4 : 75-76.

LAWLOR, M.M. (1959) Dominance relationships in the golden hamster, with special reference to the influence of heredity. Ph.D. thesis, Bedford College, London University.

LAWLOR, M.M. (1963) Social dominance in the golden hamster. BULL. BRIT. PSYCHO. SOC. 16 (51) : 25-38.

LAWLOR, M.M.; WELLS, P.A. & WEINBERG, J. (1975) The effects of infantile stimulation in the golden hamster. EXPTL. BRAIN RES. (Suppl.) 23 : Abs. 236.

LEE, M.H.S. & WILLIAMS, D. (1974) Long term changes in nest condition and pup grouping following handling of rat litters. DEVEL. PSYCHOBIOL. 8 (1) : 91-95.

LEE, M.H.S. & WILLIAMS, D. (1976) Reaction of rat females to experimental disturbance. BULL. PSYCH. SOC. 7 (6) : 489-490.

LEONARD, C.M. (1974) Thermotaxis in golden hamster pups. JN. COMP. PHYSIOL. PSYCHOLOGY 86 (3) : 458-469.

LERWILL, C.J. (1968) Agonistic behaviour and social dominance golden hamster, *Mesocricetus auratus* (Waterhouse). M.Sc. THESIS, UNIVERSITY COLLEGE OF SWANSEA.

LESTER, D. (1974) A cross-species study of exploration & learning. PERCEPTUAL & MOTOR SKILLS 39 (1:2) : 562 (Abst.)

LEVINE, S. (1956) A further study of infantile handling and adult avoidance learning. JOURNAL PERS. 25 : 70-80

LEVINE, S. (1957a) Infantile experience & resistance to physiological stress. SCIENCE 126 : 405

LEVINE, S. (1957b) Infantile experience & consummatory behaviour in adulthood. JN. COMP. PHYSIOL. PSYCHOLOGY 50 : 609-612.

LEVINE, S. (1959) Emotionality and aggressive behaviour in the mouse as a function of infantile experience. JN. GENET. PSYCHOLOGY 94 : 77-83.

LEVINE, S. (1962a) Plasma-free corticosteroid response to electric shock in rats stimulated in infancy. SCIENCE 135 : 795-6

LEVINE, S. (1962b) The psychophysiological effects of infantile stimulation. In: "Roots of Behaviour". by Bliss, E.L. (Ed.), pp 246-253, (q.v.).

LEVINE, S. (1969) An endocrine theory of infantile stimulation. In: Ambrose, J.A. (Ed.) pp. 45-54 (q.v.).

LEVINE, S. & ALPERT, M. (1959) Differential maturation of the CNS as a function of early experience. ARCHS. GEN. PSYCHIAT. 1 : 403-405.

LEVINE, S. & BROADHURST, P.L. (1963) Genetic and ontogenetic determinants of adult behaviour in the rat. JN. COMP. PHYSIOL. PSYCHOLOGY 56 (2) : 423-428.

LEVINE, S. & LEWIS, G.W. (1959) The relative importance of experimenter contact in an effect produced by extra-stimulation in infancy. JN. COMP. PHYSIOL. PSYCHOLOGY 52 : 368-369.

LEVINE, S. & MULLINS, R.F. (1968) "Hormones in infancy". In: Newton & Levine, Ch. VII pp 168-197.

LEVINE, S. & OTIS, L.S. (1958) The effects of handling before and after weaning on the resistance of albino rats to later deprivation. CAN. JN. PSYCHOLOGY 12 : 103-108.

LEVINE, S.; ALPERT, M. & LEWIS, G.W. (1957) Infantile experience and the maturation of the pituitary adrenal axis. SCIENCE (N.Y.) 126 : 1347

LEVINE, S.; ALPERT, M. & LEWIS, G.W. (1958) Differential maturation of an adrenal response to cold stress in rats manipulated in infancy. JN. COMP. PHYSIOL. PSYCHOLOGY 51 : 774-777.

LEVINE, S.; HALTMEYER, G.C.; KARAS, G.G. & DENENBERG, V.H. (1967) Physiological & behavioural effects of infantile stimulation. PHYSIOL. BHVR. 2 : 55-59.

LEVITSKY, D.A. & BARNES, R.H. (1970) Effects of early malnutrition on the reaction of adult rats to aversive stimuli. NATURE (LONDON) 225 : 468-469.

LINDZEY, G.L.; WINSTON, H.D. & MANOSEVITZ, M. (1963) Early experience, genotype and temperament in Mus musculus. JN. COMP. PHYSIOL. PSYCHOLOGY 56 : 622-629.

LISK, R.D. (1970) Mechanisms regulating sexual activity in mammals. JN. OF SEX RES. 6 (3) : 220-228.

LLOYD, B.J. (1972) Rates of adrenal cholesterol formation by the hamster, sheep, guinea pig and rat from labelled pyruvate, in vitro. GEN. COMP. ENDOCRIN. 19 : 428-431.

LOCKARD, R.B. (1963) Some effects of light upon the behaviour of rodents. PSYCHOLOGICAL BULL. 60 : 509-529.

LONG, C.N.H. (1952) Regulation of ACTH secretion. In: Recent Progress in Hormone Research, Vol. 7 (Ed.) Pincus, G.; Ch. 3, pp 75-105.

LORE, R. & FLANNELLY, K. (1977) Rat Societies. SCI. AM. 236 (5) : 106-116.

LOTT, D.F. (1962) The role of progesterone in the maternal behaviour of rodents. JN. COMP. PHYSIOL. PSYCHOLOGY 55 (4) : 610-613.

LOWN, B.A. (1979) Effects of early handling on open field activity of gerbils. PSYCHOL. REP. 44 (1): 145-146.

LUCHINS, A.S. & FORGUS, R.H. (1955) The effect of differential postweaning environment on the rigidity of animal's behaviour. JN. GENET. PSYCHOL. 86 : 51-58.

LYMAN, C.P. (1948) The oxygen consumption and temperature regulation of hibernating hamsters. JN. EXP. ZOOL. 109 : 55-78

LYMAN, C.P. & CHATFIELD, P.O. (1950) Mechanisms of arousal in the hibernating hamster. JN. EXP. ZOOL. 114 : 491-515

LYMAN, C.P. & LEDUC, E.H. (1953) Changes in blood sugar and tissue glycogen in the hamster during arousal from hibernation. JN. CELL. & COMP. PHYSIOL. 41 : 471-492

LYNCH, A. (1976) Postnatal undernutrition: an alternative method. DEVEL. PSYCHOBIOL. 9 (1) : 39-48.

LYNCH, A,; SMART, J.L. & DOBBING, J. (1975) Motor co-ordination and cerebellar size in adult rats undernourished in early life. BRAIN RES. 38 (2) : 249-259

MACHO, L. et al (1975) Response of the adrenals to stress in animals from litters with different numbers of young. PHYSIOLOGIA BOHEMOSLOVACA 24 (6) : 501-508; PSYCHOLOGICAL ABSTRACT 56 : 3590

McIVER, A.H.; JEFFREY, W.E.; STEVENSON, M. & NIELSON, H.C. (1968) Infantile handling and body temperature change in the rat. III . Early temperature change and its implications for later responses. TRANS. N.Y. ACAD. SCI. 30 : 992-1000.

McREYNOLDS, P. (1962) Exploratory behaviour : A theoretical interpretation. PSYCHOLOGICAL REP. 11 : 311-318.

MAHUT, H. (1955) Breed differences in the dog's emotional behaviour. DOCTORAL THESIS, McGILL UNIVERSITY, MONTREAL, CANADA.

MAILLOUX, J.G.; EDWARDS, H.P.; BARRY, W.F.; ROWSELL, H.C. & ACHORN, E.G. (1974) Effects of differential rearing on cortical evoked potentials of the albino rat. JN. COMP. PHYSIOL. PSYCHOLOGY 87 (3) : 475-480.

MANDL, A.M. & ZUCKERMAN, S. (1952) Factors influencing the onset of puberty in albino rats. JN. ENDOCRIN. 8 : 357-364.

MARKS, B.H.; ALPERT, M. & KRUGER, F.A. (1958) Effect of amphenone upon steroidogenesis in the adrenal cortex of the golden hamster. ENDOCRIN.63 : 75- 81.

MARQUES, D.M. & VALENSTEIN, E.S. (1976) Another hamster paradox: more males carry pups and fewer kill and cannibalize young than do females. JN. COMP. PHYSIOL. PSYCHOLOGY 90 (7) : 653-657.

MARQUES, D.M. & VALENSTEIN, E.S. (1977) Individual differences in aggressiveness of female hamsters: response to intact and castrated males and to females. AN. BHVR. 25 : 131-139.

MARSHALL, P.T. & HUGHES, G.M. (1967) "The physiology of mammals and other vertebrates." CAMB.UNIV.PRESS.

MASUR, J. & STRUFFALDI, G. (1974) Division of labour between rats: influence of differential social rearing conditions. BHVRL. BIOL. 12(2) : 233-241.

MAYER, J. (1968) "Overweight: causes, cost, and control." ENGLEWOOD CLIFFS, NEW JERSEY: PRENTICE HALL. p.73.

McMICHAEL, R.E. (1961) The effects of preweaning shock and gentling on later resistance to stress. JN. COMP. PHYSIOL. PSYCHOL. 54 : 416-421.

MELZACK, R. & SCOTT, T.H. (1957) The effects of early experience on the response to pain. JN. COMP. PHYSIOL. PSYCHOLOGY 50 : 155-161.

MEYER, J.S. & BOWMAN, R.E. (1972) Rearing experience, stress and adrenocortico-steroids in the rhesus monkey. PHYSIOL. BHVR. 8 : 339-343.

MEYERS, M.C. (1950) Studies on the adrenals of the golden hamster (Cricetus auratus) in relation to aging. ANAT. REC. 106 : 282-283.

MIYABO, S. & HISADA, T. (1975) Sex difference in ontogenesis of circadian adrenocortical rhythm in cortisone-primed rats. NATURE 256 : 590-592.

MONTGOMERY, R.L. & BERKUT, M.K. (1969) Behaviour and adrenal weights of non-stressed rats with selected limbic lobe lesions. PHYSIOL. BHVR. 4 : 745.

MORGAN, M.J. (1973) Effects of postweaning environment on learning in the rat. AN. BHVR. 21 : 429-442.

MORGAN, M.J. (1975) The effects of isolation rearing in the rat upon inhibitory phenomena. EXPTL. BRAIN RES. (Suppl.) 23 : Absts. 286.

MORTON, J.R.C. (1963) The interactive effects of preweaning and postweaning environments upon adult behaviour. DISS. ABSTS. 23 (7) : 2593.

MORTON, J.R.C. (1968) Effects of early experience "handling and gentling" in laboratory animals. In: Fox, Ch. 17, pp 261-292, (q.v.).

MORTON, J.R.C.; DENENBERG, V.H. & ZARROW, M.X. (1963) Modification of sexual development through stimulation in infancy. ENDOCRIN. 72 : 439-442.

MOS, L.; VRIEND, J. & POLEY, W. (1974) Effects of light environment on emotionality and the endocrine system of inbred mice. PHYSIOL. BHVR. 12 : 981-989.

MUHLBOCK, O. & VAN EBBENHORST TENGERGEN, W.P.J.R. (1971) "Instability of characteristics in inbred strains of mice". In: "Defining the laboratory animal". Int. Committee on Laboratory animals (IV Symposium) National Acad. of Sciences, Washington, D.C. p. 243.

MURPHY, B.E.P. (1967) Some studies of the protein-binding of steroids and their application to the routine micro and ultramicro measurement of various steroids in body fluids by competitive protein-binding radio assay. JN. CLIN. ENDOCRIN. & MET. 27 : 973-990.

MURPHY, M.R. (1970) Territorial behaviour of caged golden hamsters. PROC. ANN. CONF. AM. PSYCHOLOGICAL ASSOC. 5 (1) : 237.

MURPHY, M.R. (1971) Natural history of the syrian golden hamster - a reconnaissance expedition. AM. ZOOL. 11 : 632

MURPHY, M.R. (1978) Oestrus Turkish hamsters display lordosis toward conspecific males but attack hetero-specific males. AN. BHVR. 26 (1) : 311-312.

NEWTON, G. & LEVINE, S. (Eds.) (1968) Early experience and behaviour. (THOMAS : SPRINGFIELD, ILLINOIS).

NOIROT, E. (1972) Ultrasounds and maternal behaviour in small rodents. DEVEL. PSYCHOBIOL. 5 (4) : 371-387.

NOVAK, M.A. & HARLOW, H.F. (1975) Social recovery of monkeys isolated for the first year of life: I. Rehabilitation and therapy. DEVEL. PSYCHOLOGY 11 (4) : 453-465.

OKON, E.E. (1971) The temperature relations of vocalisations in infant golden hamsters and Wistar rats. JN. OF ZOOL. 164 : 227-237.

OLTON, D.S.; JOHNSON, C.T. & HOWARD, E. (1975) Impairment of conditions active avoidance in adult rats given corticosterone in infancy. DEVEL. PSYCHOBIOL. 8 (1) : 55-61.

PALKOVITS, M. & MITRO, A. (1968) Morphological changes in the hypothalamo-pituitary - adrenal system during early postnatal period in rats. GEN. COMP. ENDOCRIN. 10 : 253-262.

PARKES, A.S. (1945) The adrenal-gonad relationship. PHYSIOL. REVIEWS 25 : 203-254.

PARVEZ, H. & PARVEZ, S. (1975) Hypophyseo-adrenocortical role in monoamine degradation during development and adult life. EXPTL. BRAIN RES. (Suppl.) 23 : Absts. 305.

PATTERSON, F.G.; BONVILLIAN, J.D.; REYNOLDS, P.C. & MACCOBY, E.E. (1975) Mother and peer attachment under conditions of fear in rhesus monkeys (Macaca mulatta) PRIMATES 16 (1): 75-81.

PAUKER, R.S. (1948) The effects of removing seminal vesicles, prostate and testes on the mating behaviour of the golden hamster. JN. COMP. PHYSIOL PSYCHOLOGY 41 : 252-257.

PAYMAN, B.C. & SWANSON, H.H. (1980) Social influence on sexual maturation and breeding in the female mongolian gerbil (Meriones unguiculatus). AN. BEHAVIOUR. 28 (2) : 528-535.

PAYNE, A.P. (1973) The effect of androgens on isolation-induced aggression in the male golden hamster. JN. ENDOCRIN. 57 : xxxvi.

PAYNE, A.P. (1979a) Neonatal androgen administration and sexual behaviour: behavioural responses and hormonal responsiveness of female golden hamsters. AN. BEHAVIOUR 27 : 242-250

PAYNE, AP. (1979b) The attractiveness of Harderian gland smears to sexually naive and experienced male golden hamsters. AN. BEHAVIOUR 27 (3) : 897-904

PAYNE, A.P. & SWANSON, H.H. (1970) Agonistic behaviour between pairs of hamsters of the same and opposite sex in a neutral observation area. BEHAVIOUR 36 : 259-269

PAYNE, AP. & SWANSON, H.H. (1971a) Hormonal control of aggressive dominance in the female hamster. PHYSIOL. BHVR. 6 : 355-357.

PAYNE, A.P. & SWANSON, H.H. (1971b) Hormonal modification of aggressive behaviour between female golden hamsters. JN. ENDOCRIN. 51 : xvii-xviii

PAYNE, A.P. & SWANSON, H.H. (1971c) The effect of castration and ovarian implantation on aggressive behaviour of male hamsters. JN. ENDOCRIN. 51 : 217-218.

PAYNE, A.P. & SWANSON, H.H. (1972a) The effect of a supranormal threat stimulus on the growth rates and dominance relationships of pairs of male and female golden hamsters. BHVR. 42 : 1-7.

PAYNE, A.P. & SWANSON, H.H. (1972b) The effect of sex hormones on the agonistic behaviour of the male golden hamster (Mesocricetus auratus, Waterhouse). PHYSIOL. BHVR. 8 : 687-691.

PAYNE, A.P. & SWANSON, H.H. (1972c) The effect of sex hormones on aggression in the male golden hamster. JN. ENDOCRIN. 53 : lxi.

PAYNE, A.P. & SWANSON, H.H. (1973) The effects of neonatal androgen administration on the aggression and related behaviour of male golden hamsters during interactions with females. JN. ENDOCRIN. 58 : 627-636.

PEARL, J. (1963a) Avoidance learning in rodents: a comparative study. PSYCHOLOGICAL REPS. 12 : 139-145.

PEARL, J. (1963b) Effects of preshock and additional punishment on activity of hamsters. PSYCHOLOGICAL REPS. 13 (3) : 761-762.

PECZENIK, O. (1942a) Actions of sex hormones on the oestrus cycle and reproduction of the golden hamster. JN. ENDOCRIN. 3 : 157-167.

PECZENIK, O. (1942b) Some features of the golden hamster from the point of view of endocrinology. 35th CONF., SOC. EXP. BIOL., 23rd JULY, 1942.

PECZENIK, O. (1944) Action of sex hormones on the adrenal cortex of the golden hamster. PROC. ROY. SOC. EDINBURGH <u>62 (B)</u> : 59-65.

PFEIFER, W.D.; DENENBERG, V.H. & ZARROW, M.X. (1973) Decreased tyrosine hydroxylase activity in adrenal gland of adult rats that were handled in infancy. PHYSIOL. BHVR. <u>10</u> : 411-413.

PINCHOP, G.B.; CLOSE, D.P. & LONG, C.L.H. (1949) Adrenal changes produced in rats by infection with B-tubarense-B-coli. ENDOCRIN. 45 : 135-142.

PINCUS, G. (Ed.) (1952) Recent progress in hormone research. Vol. 7 ACADEMIC PRESS INC., PUBLS: N.Y.

POWELL, G.F.; BRASEL, J.A. & BLIZZARD, R.M. (1967) Emotional deprivation and growth retardation simulating idiopathic hypopituitarism. NEW ENGL. JN. MED. <u>276</u> (2) 1271-1283.

PRIESTNALL, R. (1973) Effects of handling on maternal behaviour in the mouse (<u>Mus musculus</u>): An observational study. AN. BHVR. <u>21</u> : 383-386.

RAAIJMAKERS, W.G.M. & SENNEF, C. (1975) Early undernutrition with constant maternal care: effects on later emotional behaviour and motivation in rats. EXPTL. BRAIN RES. (Suppl.) 23 : Abs. 331.

RABEDEAU, R.G. (1963) Development of sexual behaviour in the male hamster. CAN. JOURNAL PSYCHOLOGY 17 (4) : 420-429

READING A.J. (1966) Effect of maternal environment on the behaviour of inbred mice. JN. COMP. PHYSIOL. PSYCHOLOGY 62 : 437-440.

RICHARDS, M.P. (1966a) Maternal behaviour in virgin female golden hamsters (*Mesocricetus auratus*, Waterhouse). The role of the age of the test pup. AN. BHVR. 14 : 303-309.

RICHARDS, M.P. (1966b) Maternal behaviour in the golden hamster: responsiveness to young in virgin, pregnant and lactating females. AN. BHVR. 14 : 310-313.

RICHARDS, M.P.M. (1966c) Activity measured by running wheels and observation during the oestrus cycle, pregnancy and pseudopregnancy in the golden hamster. AN. BHVR. 14 (4) : 450-458.

RICHARDS, M.P.M.; BERNAL, J.F. & BRACKBILL, Y. (1976) Early behavioural differences: gender or circumcision? DEVEL. PSYCHOBIOL. 9 (1) : 89-95.

RICHTER, C.P. (1959) Rats, man and the welfare state. AM. PSYCHOLOGIST 14 : 18-28

RICHTER, C.P. (1976) Artifactual 7 day cycles in spontaneous activity in wild rodents and squirrel monkeys. JN. COMP. PHYSIOL. PSYCHOLOGY 90 (6) : 572-582.

RICHTER, C.P. & UHLENHUTH, E.H. (1954) Comparison of the effects of gonadectomy on spontaneous activity of wild and domesticated rats. ENDOCRIN.54 : 311-322

RIESS, B.F. (1954) The effect of altered environment and of age on mother-young relationships among animals. ANN. N.Y. ACAD. SCI. 57 : 606

ROBERTS, W.W.; MOONEY, R.D. & MARTIN, J.R. (1974) Thermoregulatory behaviours of laboratory rodents. JN. COMP. PHYSIOL. PSYCHOLOGY 86 : 693-699.

ROBINSON, R. (1958) Genetic studies of the Syrian hamster I: the mutant genes cream, ruby-eye and piebald. JOURNAL OF GENETICS 56 (1) : 85-102

ROSENZWEIG, M.R. (1966) Environmental complexity, cerebral change and behaviour. AM. PSYCH. 21 : 321-332.

ROSENZWEIG, M.R.; BENNETT, E.L. & DIAMOND, M.C. (1972) Brain changes in response to experience. SCI. AMER. 226 : 22-29

ROSENZWEIG, M.R.; KRECH, D,; BENNETT, E.L. & DIAMOND, M.C. (1968) "Modifying brain chemistry and anatomy by enrichment or impoverishment of experience". In: Newton & Levine (Eds.), Ch. 9; pp 258-298, (q.v.).

ROTHSCHILD (1965) A classification of living animals. LONGMANS, GREEN & CO., LTD., LONDON.

ROWELL, T.E. (1961a) The family group in golden hamsters: its formation and break-up. BEHAVIOUR 17 : 81-93

ROWELL, T.E. (1961b) Maternal behaviour in non-maternal golden hamsters. AN. BHVR. 9 : 11-15.

RUEGAMER, W.R.; BERNSTEIN, L. & BENJAMIN, J.D. (1954) Growth, food utilisation and thyroid activity in the albino rat as a function of extra handling. SCIENCE 120: 184-185

RUSSELL, P.A. (1971) "Infantile stimulation"in rodents: a consideration of possible mechanisms. PSYCHOL. BULL. 75 : 192-202.

SACKETT, G.P.; BOWMAN, R.E.; MEYER, J.S.; TRIPP, R.L. & GRADY, S.S. (1973) Adrenocortical and behavioural reactions by differentially raised rhesus monkeys. PHYSIOL. PSYCHOLOGY 1 (3) : 209-212.

SAHINEN, F.M. & SODERWALL, A.L. (1965) Accelerated senescent changes in adrenal cortex of the hamster. RAD. RES. 24 : 412-422.

SALAMA, A.A. & HUNT, J.McV. (1964) 'Fixation'in the rat as a function of infantile shocking, gentling and handling. JN. GENET. PSYCHOLOGY 105 : 131-162.

SAMORAJSKI, T,; ROLSTEN, C. & ORDY, J.M. (1971) Changes in behaviour, brain and neuroendocrine chemistry with age and stress in C57BL/10 male mice. JN. GERONT. 26 : 168-175.

SARASON, E.L. (1943) Morphologic changes in the rat's adrenal cortex under various experimental conditions. ARCH. PATH. 35 : 373-390.

SAYERS, G. (1950) "The Adrenal Cortex & Homeostasis". PHYSIOL. REV. 30 (3) : 241-320.

SAYERS, G. & SAYERS, M.A. (1948) The pituitary-adrenal system. RECENT PROGRESS IN HORMONE RESEARCH. Vol. 2 : 81-115.

SCHAEFER, G.J. & DARBES, A. (1972) The effects of preweaning handling and postweaning housing on behaviour and resistance to deprivation induced stress in the rat. DEVEL. PSYCHOBIOL. 5 (3) : 231-238.

SCHAEFER, T. (1963) Early experience and its effect on later behavioural processes in the rat. II. A critical factor in the early handling phenomenon. TRANS. N.Y. ACAD. SCI. 25 : 871-889.

SCHAEFER, T. (1968a) Some methodological implications of the research on 'early handling' in the rat. In: Newton & Levine (Eds.), "Early experience and behaviour". Ch. V, pp 102-141.

SCHAEFER, T. (1968b) Infantile handling and body temperature change in the rat. I. Initial investigations of the temperature hypothesis. TRANS. N.Y. ACAD. SCI. 30 : 977-984.

SCHALLY, A.V.; BOWERS, C.Y. & LOCKE, W. (1964) Neurohumoral functions of the hypothalamus. AMER. JN. MED. SCI. 248 : 79-101.

SCHAPIRO, S. (1968) "Maturation of the neuroendocrine response to stress in the rat." In: Newton & Levine (Eds.), Ch. 8, pp 198-257.

SCHAPIRO, S. & VUKOVICH, K.R. (1970) Early experience and effects upon cortical dendrites: a proposed model for development. SCI. (N.Y.) 167 : 292-294.

SCHELL, R.E. & ELLIOTT, R. (1967) Note on sex differences in response to stress in rats. PSYCHOLOGICAL REP. 20 : 1201-2.

SCHIFFMAN, H.R. (1971) Depth perception of syrian hamster as a function of age and photic condition of rearing. JN. COMP. PHYSIOL. PSYCHOLOGY 76 (3) : 491-495.

SCHINDLER, W.J. & KNIGGE, K.M. (1959a) Adrenal cortical secretion in the golden hamster. ENDOCRIN. 65 : 739-747.

SCHINDLER, W.J. & KNIGGE, K.M. (1959b) "In vitro studies and adrenal steroidogenesis by the golden hamster". ENDOCRIN. 65 : 748-765.

SCHNEIDER, G.E. & GROSS, C.G. (1965) Curiosity in the hamster. JN. COMP. PHYSIOL. PSYCHOLOGY 59 (1) : 150-152.

SCHUBIK et al (1962) In: "Biological interactions in normal and neoplastic growth". (Eds. Brennan & Simpson) (cited by Hoffman, Robinson & Magalhaes, 1968, q.v.)

SCOTT, J.L. (1970) Studies of maternal and pup behaviour in the golden hamster (Mesocricetus auratus). UNPUBLISHED Ph.D. THESIS, UNIVERSITY OF CAMBRIDGE.

SCOTT, J.P. (1948) Dominance and the frustration-aggression hypothesis. PHYSIOL. ZOOL. 21 : 31-39.

SCOTT, J.P. (1958) Critical periods in the development of social behaviour in puppies. PSYCHOSOM. MED. 20 (1) : 42-54

SCOTT, J.P. (1968) "Early experience and the organisation of behaviour." WADSWORTH: BELMONT, CALIFORNIA.

SEITZ, P.F.D. (1954) The effects of infantile experience upon adult behaviour in animal subjects: I. Effects of litter size during infancy upon adult behaviour in the rat. AM. JN. PSYCHIAT. 110 : 916-927.

SELYE, H. (1950) "The physiology & pathology of exposure to stress". MONTREAL: ACTA. INC.

SHARPE, R.M. (1975) The influences of sex of litter-mates on subsequent maternal behaviour in *Rattus norvegicus*. AN. BHVR. 23 (3) : 551-559.

SHERROD, K.B.; CONNOR, W.H. & MEIER, G.W. (1974) Transient and enduring effects of handling on infant and maternal behaviour in mice. DEVEL. PSYCHOBIOL. 7 (1) : 31-37.

SHIMADA, M. & LANGMAN, J. (1970) Cell proliferation, migration and differentiation in the cerebral cortex of the golden hamster. JOURNAL COMP. NEUR. 139 : 227-244

SIMPSON, G.G. (1945) The principles of classification and a classification of mammals. BULLETIN AM. MUS. OF NATURAL HISTORY 85

SLOB, A.K.; SNOW, C.E. & DeNATRIS-MATHOT, E. (1973) Absence of behavioural deficits following neonatal undernutrition in the rat. DEVEL. PSYCHOBIOL. 6 : 177-186

SLUCKIN, W. (Ed) (1971) "Early learning and early experience." PENGUIN MODERN PSYCHOLOGY READINGS.

SMALLEY, R.L. & SMALLEY, K.N. (1967) Brown and white fats: development in the hamster. SCIENCE 157 : 1449-1451

SMART, J.L. (1974) Activity and exploratory behaviour of adult offspring of undernourished mother rats. DEVEL. PSYCHOBIOL. 7 (4) : 315-321.

SMART, J.L. (1976) Maternal behaviour of undernourished mother rats towards well fed and underfed young. PHYSIOL. BHVR. 16 (2) : 147-149.

SMITH, A.M. (1967) Infantile stimulation and the Yerkes-Dodson Law. CANADIAN JOURNAL OF PSYCHOLOGY 21 (4) : 285-293.

SMITH, M.L. & SIMMEL, E.C. (1977) Paternal effects on the development of social behaviour in Mus musculus. DEVEL. PSYCHOBIOL. 10 (2) : 151-159.

SMOTHERMAN, W.P.; WIENER, S.G.; MENDOZA, S.P. & LEVINE, S. (1977) Maternal pituitary-adrenal responsiveness as a function of differential treatment of rat pups. DEVEL. PSYCHOBIOL. 10 (2) 113-122.

SNYDER, J.G. & WYMAN, L.C. (1951) Gonadal influences on survival after adrenalectomy in the golden hamster. ENDOCRIN. 49 : 205-212.

SODETZ, F.J.; MATALKA, E.S. & BUNNELL, B.N. (1967) Septal ablation and affective behaviour in the golden hamster. PSYCHON. SCI. 7 (5) : 189-190.

SOLKOFF, N.; YAFFE, S.; WEINTRAUB, D. & BLASE, B. (1969) Effects of handling on the subsequent developments of premature infants. DEVEL. PSYCHOBIOL. 1 : 765-768.

SOUMALAINEN, P. (1959) Paper presented at the First International Conference on Hibernation, Harvard University. Quoted by DENYES & HORWOOD (1960) (q.v.). CAN. JN. BIOCHEM. PHYSIOL. 38 : 1479.

SPECTOR, W.S. (Ed.) (1956) "Handbook of Biological Data". W.B. SAUNDERS COMPANY: PHILADELPHIA & LONDON.

SPEIRS, R.S. & MEYER, R.K. (1949) The effects of stress, adrenal & adrenocorticotrophic hormones on the circulating eosinophils of mice. ENDOCRIN. 45 : 403-429.

STANLEY, M. (1971) An ethogram of the hopping mouse, Notomys alexis. Z. TIERPSYCHOL. 29 : 225-258.

STEEL, E. (1979) Male-female interaction throughout the oestrus cycle of the syrian hamster (Mesocricetus auratus). AN. BHVR. 27 (3) : 919-929.

STEEL, E. (1980) Changes in female attractivity and proceptivity throughout the oestrus cycle of the syrian hamster. (Mesocricetus auratus). AN. BHVR. 28 (1) : 256-265.

STERMAN, M.B.; McGINTY, D.J. & ADINOLFI, A.M. (1971) 'Brain development and behaviour'. ACADEMIC PRESS, N.Y. & LONDON.

SUGITA, N. (1918) Comparative studies on the growth of the cerebral cortex. JOURNAL COMP. NEUR. 29 : 1-9; 11-39; 61-117; 119-161; 177-278.

SUOMI, S.J. & HARLOW, H.F. (1975) Effects of differential removal from group on social development of rhesus monkeys. JN. CHILD. PSYCHOLOGY PSYCHIAT. ALL. DISCIP. 16 (2) : 149-164.

SVARE, B.B. & LESHNER, A.I. (1973) Behavioural correlates of intermale aggression and grouping in mice. JN. COMP. PHYSIOL. PSYCHOLOGY 85 (1) : 203-210.

SWAAB, D.F. & SCHADE, J.P. (1974) "Progress in brain research, Vol. 41: Integrative Hypothalamic Activity". ELSEVIER SCIENTIFIC PUBL. CO., AMSTERDAM.

SWANN, H.G. (1940) "The Pituitary-Adrenocortical Relationship". PHYSIOL. REV. 20: 493-521

SWANSON, H.H. (1966) Sex differences in behaviour of hamsters in openfield and emergence tests: effects of pre & post-pubertal gonadectomy. AN. BHVR. 14 (4) : 522-529.

SWANSON, H.H. (1967) Alteration of sex-typical behaviour of hamsters in openfield and emergence tests by neonatal administration of androgen or oestrogen. AN. BHVR. 15 (2-3) : 209-216

SWANSON, H.H. (1969) Interaction of experience with adrenal and sex hormones on the behaviour of hamsters in the openfield test. AN. BHVR. 17 (1) : 148-154.

SYKES, E.A.B. (1962) Some aspects of visual discrimination in the golden hamster. M.Sc. THESIS, BEDFORD COLL., UNIVERSITY OF LONDON.

SYKES, S.E. & CHEYNE, J.A. (1976) The effects of prenatal and postnatal protein malnutrition on physical and motor development of the rat. DEVEL. PSYCHOBIOL. 9 (3) : 285-295.

TEES, R.C. (1969) Effects of early visual restriction on subsequent activity and emotionality in the rat. JN. GENET. PSYCHOLOGY 114 : 193-202.

THOMAN, E.B. & LEVINE, S. (1969) Role of maternal disturbance and temperature change in early experience studies. PHYSIOL. BHVR. 4 : 143-145.

THOMPSON, E.A. & DeWEID, D. (1973) The relationship between the antidiuretic activity of rat eye plexus blood and passive avoidance behaviour. PHYSIOL. BHVR. 11 (3) : 377-380.

TILNEY, F. (1933) Behaviour in its relation to the development of the brain, II. BULL. NEUROL. INST., N.Y., 3 : 252-358.

TIMIRAS, P.S. (1972) "Developmental Physiology & Aging". NEW YORK & LONDON.

TOBACH, E. & GOLD, P. (1962) Eliminative response in the albino hamster. NATURE (LONDON) 196 : 352-355.

TOLMAN, E.C. (1954). Freedom and the cognitive mind. AM. PSYCHOLOGIST 9 : 536-538.

TORDA, C. (1975) Aggression and/or anxiety (Contribution to postnatal biochemical and behavioural origins). EXPTL. BRAIN RES. (Suppl.) 23 : Abs. 395.

UHRICH, J. (1938) The social heirarchy in albino mice. JN. COMP. PSYCHOL. 25 : 373-413.

URBAN, I. & DeWIED, D. (1975) Differences in hippocampal RSA in vasopressin deprived Brattleboro rats: effect of DG-AVP. EXPTL. BRAIN RES. (Suppl.) 23 : Abs. 401.

VAN WOERDEN, G.J.M. & RAAIJMAKERS, W.G.M. (1975) The influence of early experience on brain weight, brain acetylcholinesterase activity, and on the inhibition of irrelevant responses in the rat. EXPTL. BRAIN RES. (Suppl.) 23 : Abs. 407.

VERMES, I. & TELEGDY, G. (1975) Effect of stress on serotonin metabolism in the limbic system in rats. EXPTL. BRAIN RES. (Suppl.) 23 : Abs. 412.

VERNE, J. & HERBERT, S. (1951) Les types lipidiques de la cortico-surrenalle chez les mammiferes le classification et le signification. ANN. D'ENDOCRINOL. 12 : 192-198.

VILLESCAS, R.; BELL, R.W.; WRIGHT, L. & KUFNER, M. (1977) Effect of handling on maternal behaviour following return of pups to the nest. DEVEL. PSYCHOBIOL. 10 (4) : 323-329.

WACHS, T.D. (1974) Can early handling 'buffer' animal against intense stimulation effects? DEVEL. PSYCHOBIOL. 7 (5) : 385-392.

WADE, G.N. (1968) "Sex hormones, regulatory behaviours and body weight". In: Hoffman et al (1968) (q.v.).

WALCHER, D.H. & PETERS, D.L. (Eds) (1971) "Early childhood: The development of self regulatory mechanisms." N.Y. : ACADEMIC PRESS.

WALK, R.D. (1960) Response of dark and light-reared rats to stimulus change. JN. COMP. PHYSIOL. PSYCHOLOGY 53 : 609-611.

WALKER, E.P. (1968) "Mammals of the World" Vol.II p. 818 (2nd edition) JOHN HOPKINS PRESS, BALTIMORE.

WALSH, R.N.; BUDTZ-OLSEN, O.E.; TOROK, A. & CUMMINS, R.A. (1971) Environmentally induced changes in the dimensions of the rat cerebrum. DEVEL. PSYCHOBIOL. 4 : 115-122.

WALSH, R.N.; CUMMINS, R.A. & BUDTZ-OLSEN, O.E. (1973) Environmentally induced changes in the dimensions of the rat cerebrum: A replication and extension. DEVEL. PSYCHOBIOL. 6 : 3-7.

WALTERS, G.C. & ABEL, E.L. (1971) Passive avoidance learning in rats, mice, gerbils and hamsters. PSYCH. SCIENCE 22 (5) : 269-270

WARING, A. & PERPER, T. (1980) Parental behaviour in Mongolian gerbils (Meriones unguiculatus).II: Parental interactions. AN. BHVR. 28 (2) : 331-340.

WARREN, W.G. & IVINSKIS, A.(1973) Isolation-rearing effects on emotionality of hooded rats. PSYCHOLOGICAL REP. 32 (3) : 1011-1014.

WATERHOUSE, G.R. (1846) A natural history of the mammalia, Vol. II: Rodentia. LONDON, PARIS, BAILLIERE.

WATERMAN, A.J. (1948) "A laboratory manual of comparative vertebrate embryology". HENRY HOLT & CO. INC., N.Y., U.S.A.

WATSON, F.M.; HENRY, J.P. & HALTMEYER, G.C. (1974) Effects of early experience on emotional and social reactivity of CBA mice. PHYSIOL. BHVR. 13 (1) : 9-14.

WEINEGER, O. (1953) Mortality of albino rats under stress as a function of early experience. CAN JN. PSYCHOLOGY 7 : 111-114.

WEINSTEIN, H. & DRISCOLL, J.W. (1972) Immobilisation-produced gastric pathology in wild rats (Rattus novegicus). PHYSIOL. BHVR. 9 : 39-41.

WELLS, P.A. (1975) The influence of early handling on the temporal sequence of activity and exploratory behaviour in the rat. Ph.D. THESIS, BEDFORD COLLEGE, UNIVERSITY OF LONDON.

WERBOFF, J. & HAVLENA, J. (1963) Febrile convulsions in infant rats, and later behaviour. SCIENCE (N.Y.) 142 : 684-685.

WESTPHAL, U. (Ed.) (1971) "Steroid-protein interactions". MONOGRAPHS ON ENDOCRINOLOGY. Vol. 4.

WEXLER, B.C. (1951) Effect of a single injection of diethylstilbestrol on the adrenal cortex in the golden hamster. ENDOCRIN. 49 : 36-44.

WEXLER, B.C. (1952) Adrenal ascorbic acid changes in the gonadectomised golden hamster following a single injection of diethylstilbestrol. ENDOCRIN. 50 : 531-536.

WHIMBEY, A.E. & DENENBERG, V.H. (1967) Two independent behavioural dimensions in openfield performance. JN. COMP. PHYSIOL. PSYCHOLOGY 63 (3) : 500-504.

WIEGANT, V.M. & GISPEN, W.H. (1975) Behaviourally active ACTH analogs and brain cyclic AMP. EXPTL. BRAIN RES. (Suppl.) 23 : Abs. 433.

WILLIAMS, D.I.; BAILEY, G.B. & LEE, M.H. (1975) Handling rat pups after early weaning. BHVRL. BIOL. 13 (4) : 505-509.

WILLIER, B.H. (1924) The endocrine glands and the development of the chick. AMER. JN. ANAT. 33 : 57-67.

WILSON, M.; WARREN, J.M. & ABBOTT, L. (1965) Infantile stimulation, activity and learning by cats. CHILD DEVEL. 36 : 843-853.

WINANS, S.S. & POWERS, J.B. (1974) Neonatal and two-stage olfactory bulbectomy: effects on male hamster sexual behaviour. BHVRL. BIOL. 10 (4) : 461-471.

WINER, B.J. (1962) "Statistical principles in experimental design". NEW YORK: McGRAW-HILL.

WISE, D.A. (1974) Aggression in the female golden hamster: effects of reproductive state and social isolation. HORM. BHVR. 5 (3) : 235-250.

WITTER, A. & VERHOEF, J. (1975) The in vivo fate of a behaviourally potent ACTH analogue. EXPTL. BRAIN RES. (Suppl.) 23 : Abs. 438.

WOODS, J.W. (1957a) The effects of long-term exposure to cold upon adrenal weight and ascorbic acid content in wild and domesticated norway rats. JOURNAL PHYSIOL. 135: 384-389.

WOODS, J.W. (1957b) "The effects of acute stress & of ACTH upon ascorbic acid and lipid content of the adrenal glands of the wild rat". JOURNAL PHYSIOL. 135 : 390-399.

WORTIS, J. (Ed) (1963) "Recent advances in Biological Psychiatry," VOL. 5. N.Y.:PLENUM.

WRIGHT, L.L.; BELL, R.W.; SCHREIBER, H.L.; VILLESCAS, R. & CONELY, L. (1977) Interactive effects of parity and pup stress on the maternal behaviour of Rattus Novegicus. DEVEL. PSYCHOBIOL. 10 (4) : 331-337.

WURTMAN, R.J. & WEISEL, J. (1969) Environmental lighting and neuroendocrine function: relationship between spectrum of light source and gonadal growth. ENDOCRIN. 85 : 1218-1221.

WYLY, M.V.; DENENBERG, V.H.; SANTIS D.de, BURNS, J.K. & ZARROW, M.X. (1974) Handling rabbits in infancy: in search of a critical period. DEVEL. PSYCHOBIOL. 8 (2) : 179-186.

YARON, E.; CHOVERS, I.; LOCKER, A. & GROEN, J.J. (1963) Influence of handling on the reproductive behaviour of the syrian hamster in captivity. JN. PSYCHOSOMATIC RES. 7 : 69-82. -

ZERBOLIO, D.J. (1974) Wild caught versus inbred mouse strains:
differences in wheelturn avoidance learning.
BULL. PSYCH. SCI. 4 (1) : 24-26.

ZIEGER, G.; LUX, B. & KUBATSCH, B. (1974) Sex dimorphism
in the adrenals of hamsters. ACTA ENDOCRIN.
75 (3) : 550-560.

APPENDICES

APPENDIX A: Behavioural observations

These observations were made in a very general manner during routine inspections of the litters. Such data are too casual for inclusion in the main text although they may be considered valuable indicators for future research. Detailed examination of behavioural and physical development, social and maintenance behaviours and maternal behaviour shown in the various conditions could show significant differences and so provide better indicators to the true mediators of the experimental effects produced in this field of study.

The only quantitative behavioural data obtained were those on maternal behaviour - but due to the small sample size these cannot be considered definitive.

ON GENERAL BEHAVIOUR

In general the burrow-reared (B-L) pups appeared much quieter than those in the lab (L-L), both focally and actively; and were also more responsive to intrusion and disturbance. Those pups which were handled became increasingly nervous of intrusion and very difficult to handle. It is difficult to say if there were any clearcut differences in physical development with this causal observation although it did seem that eye-opening, which has been used as a measure of accelerated development in handled rats, was not accelerated (indeed slightly delayed) in either the handled or the burrow conditions as compared with the laboratory control. Coat growth appeared to be differentially affected with those animals in the burrow producing much better coats quicker, whilst the handled pups were somewhat behind. Burrow reared pups were quieter than lab or handled whilst the handled pups were always noisiest and began fighting amongst themselves earlier. This fighting behaviour was particularly noticeable in the handled group and continued throughout the animals lifespan, often very viciously. As these handled groups matured there was much fighting - often causing physical damage, including several animals that had bitten chests suggesting that the natural submissive postures no longer functioned in arresting aggression. Many of the animals had damaged feet due to being bitten whilst hanging in the cage corners - an activity that seemed to occur frequently to escape littermates. This aggressive behaviour was accompanied by a great deal of vocalisation. Occasionally cagemates had to be separated to prevent excessive overt aggression - a problem not commonly found in this laboratory, as a stable social relationship is normally built up within a cage of littermates. It was difficult using these rough observations to make any clear distinction between those groups that received different handling treatments - again a more vigorous study may prove useful in revealing differences not demonstrated here.

ON MATERNAL BEHAVIOUR

Detailed observations was made, using time-lapse video recording, of the maternal behaviour in two litters - one raised in the lab and the other in the burrow condition - during the 'light' period of the diurnal cycle. Both the measures used showed significant differences between the two conditions - the female in the lab condition came off the nest fewer times, spent less time off the nest during the day and also was away from the nest for shorter periods (see figures a,b and c). As well as these quantitative differences there were considerable qualitative differences in the behaviour of the two females. The female in the burrow was more entrained to the light cycle - shown by the fact her activity tended to occur in bunches, particularly at the beginning and end of the day; she also followed distinct 'routes' within her cage when active whilst the lab female appeared to move in a totally haphazard fashion. This could be interpreted as simply a stereotyping of behaviour, but the impression was one of an animal 'checking' its environment. Again, although both females characteristically responded to the daily feeding of fresh carrot with an activity burst, the female in the lab was far less reactive - to this and to any other disturbances.

In general, then, the behaviour of the two females was felt to reflect the two environments in which they found themselves - the burrow female appeared to approach the adaptive behaviour of a nocturnal rodent in its wild state whilst that of the lab female showed an adjustment of behaviour to cope with the increased visual, auditory and olfactory input of a typical animal room.

At first appearance the quantitative data indicate that the lab female showed better maternal behaviour in that she did not leave the pups as much as the burrow female. Indeed, the burrow female was observed (particularly after the first few days) to sleep off the nest for quite lengthy periods (this may be a natural occurrence - see D'Souza and Martin, 1974 on maternal behaviour in tree shrews), whilst the lab female was never seen to do this.

Figure a. Maternal behaviour: Number of times female leaves the nest in 12 hour light period.

Figure a

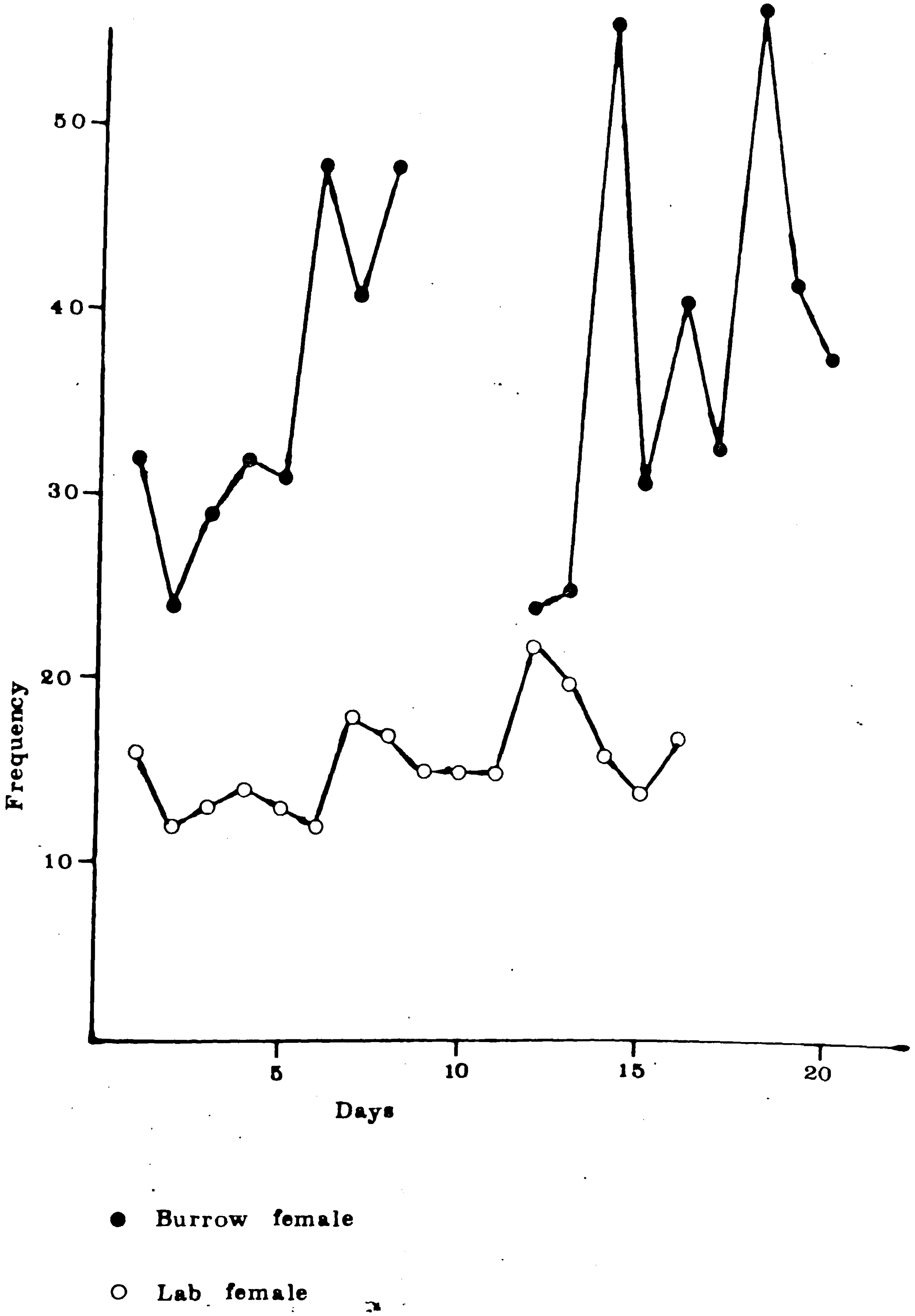

50
40
30
20
10
Frequency
5
10
15
20
Days
● Burrow female
○ Lab female

Figure b. Maternal behaviour: Total amount of time spent off nest by female during 12 hour light period.

Figure b

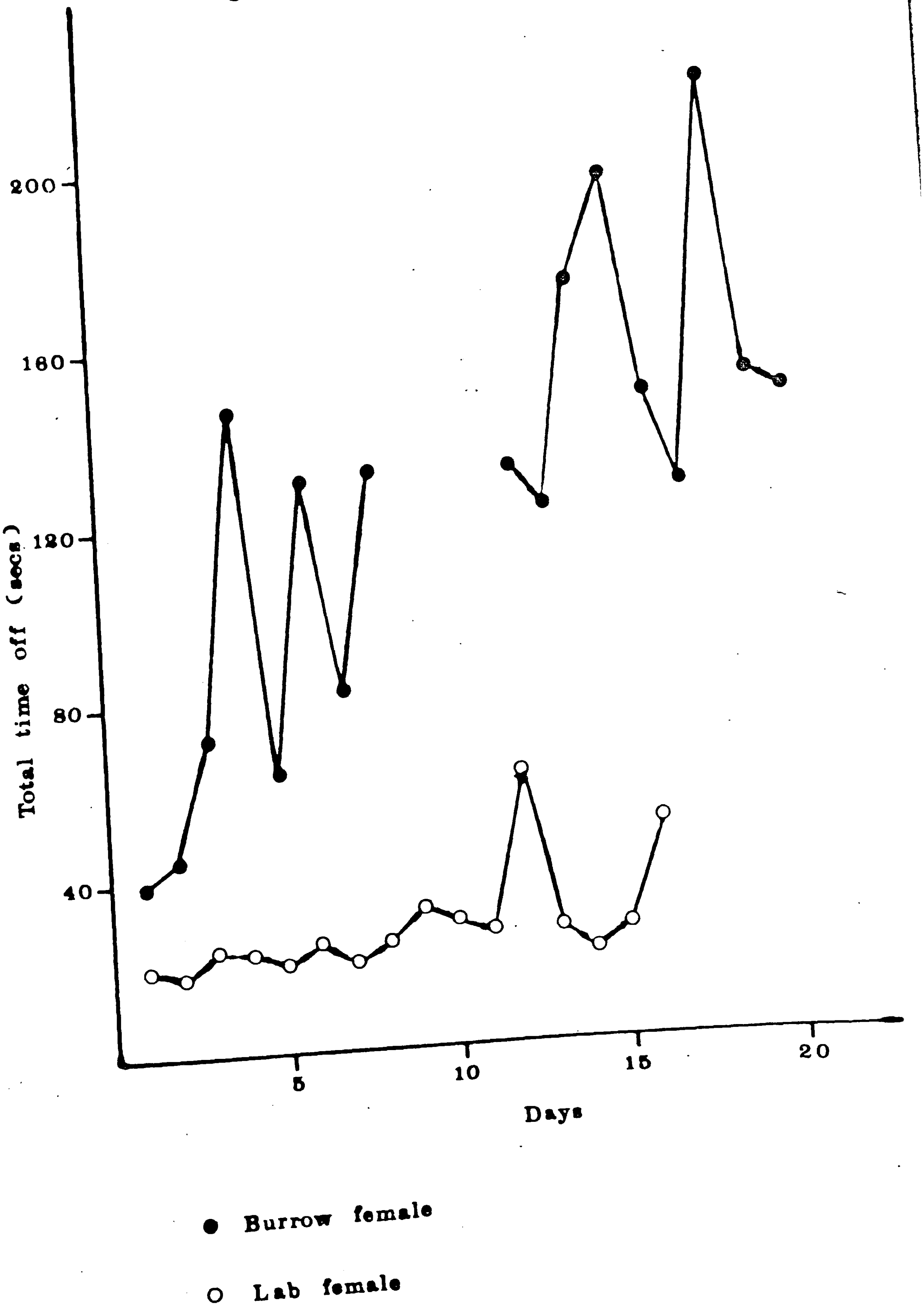
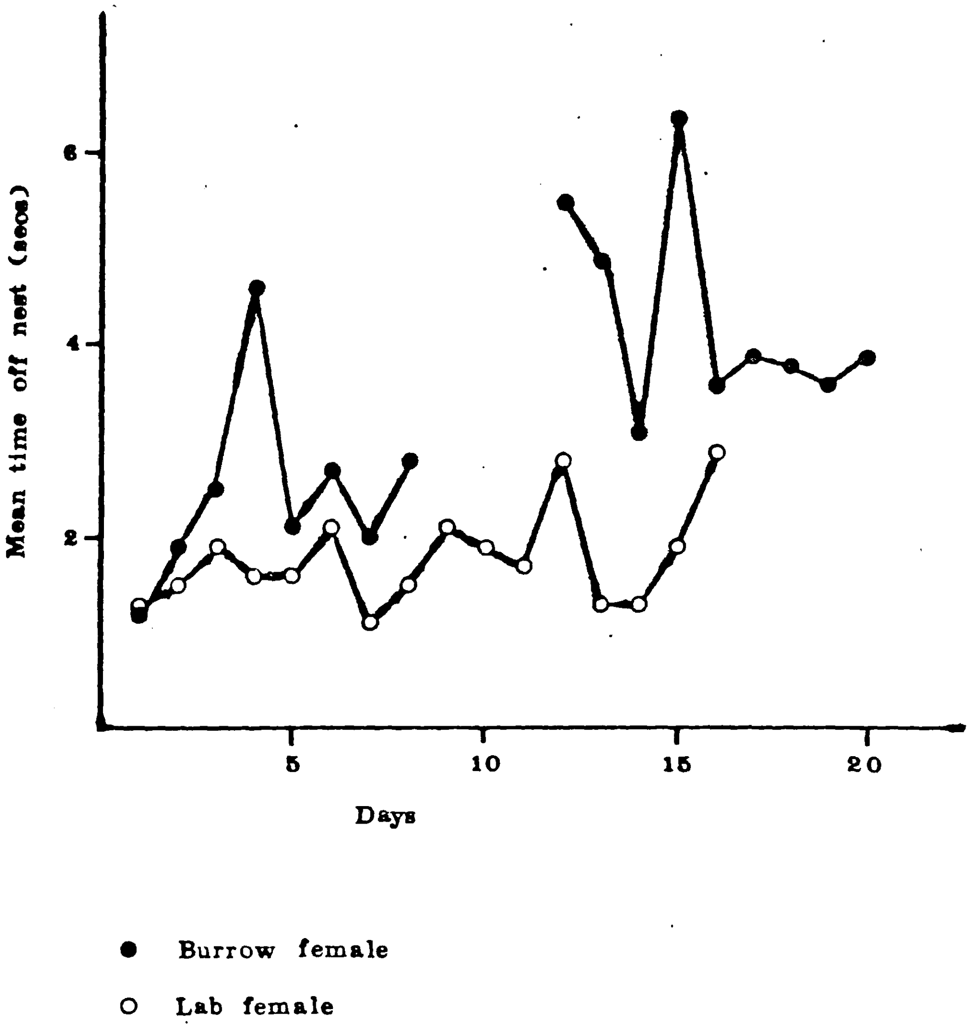

200
160
120
80
40
Total time off (secs)
5
10
15
20
Days
● Burrow female
○ Lab female

Figure C. Maternal behaviour: Mean time spent off nest by female.

Figure C


Mean time off nest (secs)
2
4
6
5
10
15
20
Days
● Burrow female
○ Lab female

However, observations on the state of the nests were carried out (for nest ratings see Scott, 1970; see also Daly, 1971) and these showed that litters reared in the burrow had consistently better nests and that these nests were maintained longer than those in the light. The nests, and cages as a whole, of the litters in the burrow condition appeared cleaner and more organised than those in the lab. Admittedly, the average size of the litters in the lab was slightly greater than in the burrow, but this does not seem an adequate explanation, and the overall lasting impression was one of improved, purposeful maternal behaviour in the burrow condition.

From observation in the handled groups the females behaviour was, in general, very similar to that of the lab female. They appeared totally unbothered when handling was initiated although invariably they reacted afterwards, but not necessarily immediately. They suddenly seemed to realise something had occurred - and would furiously nestbuild, to the extent of disturbing the original nest completely and pushing the pups about in the wood chips. Often a pup would be picked up and carried out the cage until the female settled again. This response died out once the pups all became active themselves. This extreme type of behaviour has been reported elsewhere in rats (Birke, pers. comm.) and seems to indicate an effect on the female of the pups handling, via some olfactory or auditory cue, to produce exaggerated maternal behaviour. The nest ratings in this group seem to give support to this theory in that initially the nests are good and seem well maintained but after the first week they decline rapidly. Again the pups' behaviour has some bearing on this as they become more active and boisterous.

The nest ratings are the only quantitative data obtained in all conditions, and the differences amongst the experimental conditions burrow, lab and handled days 0-21 are demonstrated in figure d. An analysis of variance does not however attain the 5% level in the main conditions effect nor in the interaction (table a). It is interesting to note here that the females in the handled group did seem to retrieve their pups longer and also to nurse them until much older, whereas those in the burrow ceased both activities sooner.

It is not possible to analyse the nest ratings from the early handling conditions due to the separate time spans of those conditions. In general, the females have relatively good nests in all conditions, at least comparable to the control group. Both the age of the pups, the siz of the litter and the amount of handling occurring appear important variables in the breakdown of the nest. It is interesting that the group obtaining the highest nest ratings throughout the experimental period, and the only group to show an increase in nest rating during that period (in fact, over the first four days), was the NH group. The suggestion that mild interference may promote maternal care, whilst excessive interference encourages inappropriate maternal care cannot be ignored. It may therefore be stated that differential maternal behaviour is produced in the three basic early conditions (i.e. burrow, lab and handled - which are considered to be on a 'stimulation continuum') - and that those females in the burrow condition give best care to their young whilst those in the handled condition, do worst.

Table a: Analysis of nest ratings in the three experimental conditions (burrow, laboratory and handled days 1-21); nests rated post parties days 2/3 and 11/12.

Source	SS	d.f.	mS	F	p
Conditions	2.11	2	1.06	2.37	n.s.
Error	2.67	6	0.45		
Total subjects	4.78	8			
Trials	10.89	1	10.89	19.45	< 0.015
T X C	4.78	2	2.39	4.27	< 0.1
Error	3.33	6	0.56		
Total variance	23.78	17			

Figure d. Nest ratings in neonatal conditions.

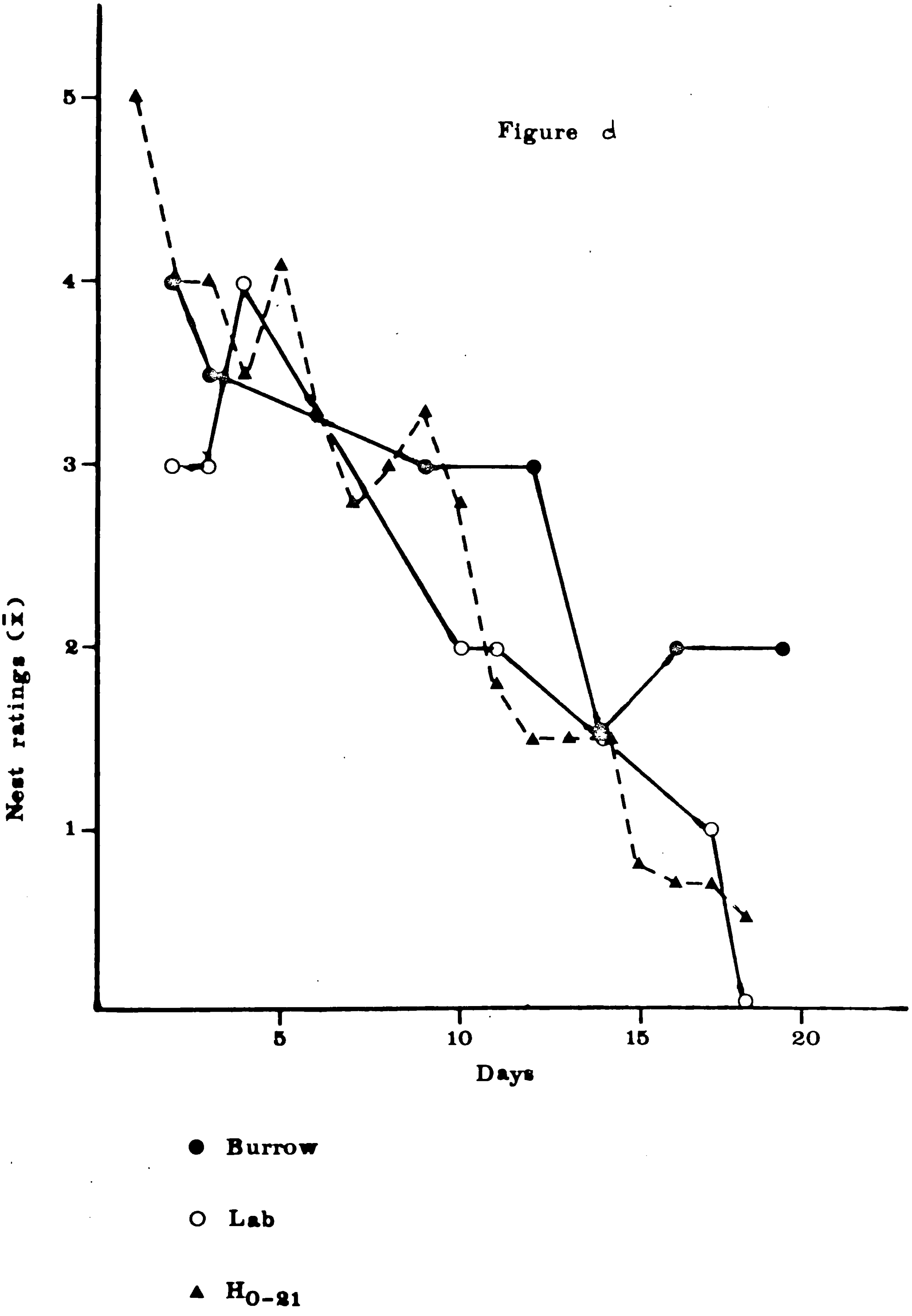


Figure d

ON POST-WEANING BEHAVIOUR

These observations were made on the animals in the free-enriched environment, compared with those in the laboratory postweaning. As already mentioned the two groups did seem to differ pre-weaning with regard to the amount of noise made, general activity levels and responsiveness to intrusion. When put into their post-weaning conditions (desert or lab) these differences seemed to continue to a certain degree. In the deserts, the burrow-reared pups usually settled more quickly when first introduced and were also quieter once established - at least during the day. This is possibly only a reflection of the fact that they seemed more light entrained than those pups that were reared in the lab.

The use made of the desert was very similar whatever the initial environmental experience - full use of the space available was made with several nests established and usually one main urination spot. Faeces and food(i) and often some of the objects in the environment, were frequently stored in one of the nest boxes to the exclusion of anything else.

(i) This storage of faeces - which is a positive active behaviour on the part of the hamster, together with the fact there seems to be a retention of faecal matter in novel environments, such as the open-field, suggests that there is some dietary significance for this action, although the use as a territorial marker cannot be ruled out. Bearing in mind their natural diet and environment the fact that these stores grow some form of fungal matter upon them, which might be rich in forms of Vitamin B bears some thought. This form of dietary supplementation has been shown in ants.

Only the smaller, lighter objects were moved about - obviously in the hope that they may prove edible at a later time.(ii)

As the animals approached sexual maturity the level of activity increased greatly, much more so than is apparent among animals in standard cages. This seemed mainly due to sexual precociousness on behalf of the males which resulted in a lot of chasing and fighting. It is possible that some of this behaviour, particularly in the last week and in the females, was also related to attempts to establish territory - especially in the case of several large, aggressive females. When caged in standard cages at maturity those animals, again particularly the females, seemed to have more trouble settling in the cages than those which had been caged throughout and often one animal would establish dominance over the others.

Despite these rather aggressive tendencies - which may be interpreted as a reversion to more natural, 'wild' patterns of behaviour - all the animals reared in the deserts were very healthy and good-looking animals - their differences did not go so far as actual bloodshed. It was always the females, particularly a pair of female littermates that had escaped and lived free for a short period with one of the females establishing complete dominance over the other, rather than the males, that showed the most aggressive tendencies.

(ii) It must be noted here that from the six litters reared in the desert post-weaning condition two litters had the opportunity (unintentional) of escape. Most were recaptured fairly quickly (within 24 hours) but two females from one litter were loose for seven days during which time they demonstrated their ability to orientate extremely well within a large complex, novel environment - the basement of one of the college buildings. They returned to the experimental room to obtain food but did not inhabit this room preferring to establish themselves in far flung corners of the geographers filing cabinets. It is not clear whether the two animals stayed together throughout this time although they were eventually trapped together in a rodent field trap, and their subsequent behaviour towards each other did indicate some past social history. None of the animals that escaped were excluded from the testing procedures as they had after all only experienced a somewhat more enriched environment than intended and had not drastically altered the experimental variables.

The feeling from these animals was that given the chance of a larger environment with less human interference they would revert to a much wilder type of behaviour and social organisation, and that the laboratory situation is indeed artificial and produces a partially domesticated animal.

This view may appear untenable after examination of results from the standard type of experimental measure (see main text) and also with reference to Murphy (1971), who has demonstrated no difference between laboratory bred and wild caught hamsters.

In conclusion to this section it has therefore again been indicated that the course for future experiments may well be in studies of behaviour patterns and social organisation exhibited under various experimental conditions. This type of ethological approach appears more productive and insightfull than standard procedures which are open to interpretation.

ON OPEN-FIELD BEHAVIOUR

Observations during testing suggest that measures of open-field emotionality could usefully include, in addition to ambulation and rearing, measures of the manner of locomotion, incorporating: (i) the amount of freezing, (ii) the ease with which the animal crosses the centre of the field; and (iii) the closeness of the abdomen to the ground. All of these are easily observed but hard to define in satisfactory quantitative terms (see also discussion in main text p.275).

An example of where such a measure may have been useful is given by the open-field behaviour of the handled groups of animals. These animals wash less in the open-field and are less likely to cross the centre of the field, particularly during the first day of testing. Although some of these handled animals may attain fairly high open-field ambulation scores their manner in doing so is not easy and relaxed, as shown, for example, by some of the animals from the environmental study, but an extremely nervous, frantic behaviour. In particular, they ambulate with their abdomens very close to the ground.

APPENDIX B: Equivalent age periods of various species

Waterman (1948) Developmental Stages

1 rat fetal day ≡ 1.5 day fetal g. pig
2.5 day fetal dog/cag
3.3 day fetal sheep/goat

(Hamster ≡ opossum at birth)

Himwich (1973) Physiological Stages

Human 15.5 months after birth → 20 months after birth
Rat 13 days after birth → 17.5 days after birth

Human 6.3 months fetal → 1 month after birth
Monkey 75 days fetal → 110 days fetal

Human 7 months fetal → 5 months after birth
Cat 59 days fetal → 15 days after birth

Rat 9 days after birth → 20 days after birth
Rabbit 9.5 days after birth → 18 days after birth

Rat birth → 26.5 days after birth
Hamster 3.3 days after birth → 17.4 days after birth

Crain (1952)

g.pigs 41-46 days fetal ≡ rat 7-10 days after birth

APPENDIX C: Objects used in the enriched ('desert') environment

3 plastic golf balls (4cm diameter)
6 wooden cubes (2cm)
1 long wooden cylinder (2cm x 9cm)
1 short wooden cylinder (2cm x 4.5 cm)
1 thick metal cylinder (1.5cm x 3.75 cm)
1 thin metal cylinder (0.7 cm x 5.75cm)
1 wooden block (2.5cm x 3.8cm x 1.5cm)
2 metal hoops (2cm diameter)
2 metal chains (45cm long)
2 (birdcage) ladders
2 cardboard rolls (7.6cm long)
1 cigarette box
1 animal handler (with doors open and no top)
2 cardboard hoops (4cm diameter)
½ egg box
various bricks, stones and twigs

APPENDIX D: Method for cortisol estimation

Add 0.5ml plasma to 4.5ml ethanol. Mix on rotamix and then mix tubes on blood cell suspension mixer for 5 minutes. Spin at 3000 rpm for 10 minutes. Transfer 1ml aliquots of supernatant into duplicate 7.5cm x 1.5cm plastic tubes. Dry at 45 degrees C with the aid of air for 50-60 minutes. When dry place tubes in an ice-water tray with standards and controls. Add 1ml CBG (cortisol binding globulin) solution - made up with 5μCi, 0.7ml pregnancy plasma from third trimester and 100ml barbital buffer with pH 7.4 - to each tube with a Cornwall syringe. Mix tubes on rotamix for about 3 seconds. Incubate for 10 minutes at 45 degrees C and then place in ice-water tray for a further 10 minutes. Add 0.5ml charcoal solution (1% charcoal in buffer at pH 7.4 with added bovine serum albumin) using a repette. Mix each tube gently on rotamix and leave to stand for 10 minutes. Spin at 0 degrees C for 10 minutes at 2000 rpm. (The centrifuge buckets should be precooled). Tip over in counting pots and add 10ml scintillation fluid. Count (for radioactivity). Standard tubes are set up by diluting 1ml of working standard to 250ml with ethanol. The solution in then used to set up tubes containing a known amount of cortisol - for example, 0.3ml of above standard solution contains 12μg cortisol/100ml. The standards are dried at 45 degrees C for 20 minutes. Two control plasma tubes are set up with each assay. Control '0' should read less than 1.0μg/100 mls and control 'C' should read about 10μg/100mls. The standard curve is plotted with count (in time) against μg cortisol. The levels of samples may then be read of from the standard curve. (for reference see Murphy, 1967).

APPENDIX E: A taxonomic classification of the golden hamster

Such a classification appears useful in order to determine the relationship between this species and other commonly encountered rodents. For more detail the reader is referred to Ellerman (1941, 1949), Simpson (1945) and Rothschild (1965), from which the following classifications (a-d) have been taken.

a. Classification of the hamsters

PHYLUM	Chordata
SUBPHYLUM	Vertebrata
CLASS	Mammalia
SUBCLASS	Theria
INFRACLASS	Eutheria
ORDER	Rodentia
SUBORDER	Myomorpha
SUPERFAMILY	Muroidea
FAMILY	Cricetidae
SUBFAMILY	Cricetinae
TRIBE	Cricetini
GENERA	Calomyscus (1)
	Phodopus (2)
	Cricetus (2)
	Cricetulus (2)
	Mesocricetus (2)
	Mystromys (3)

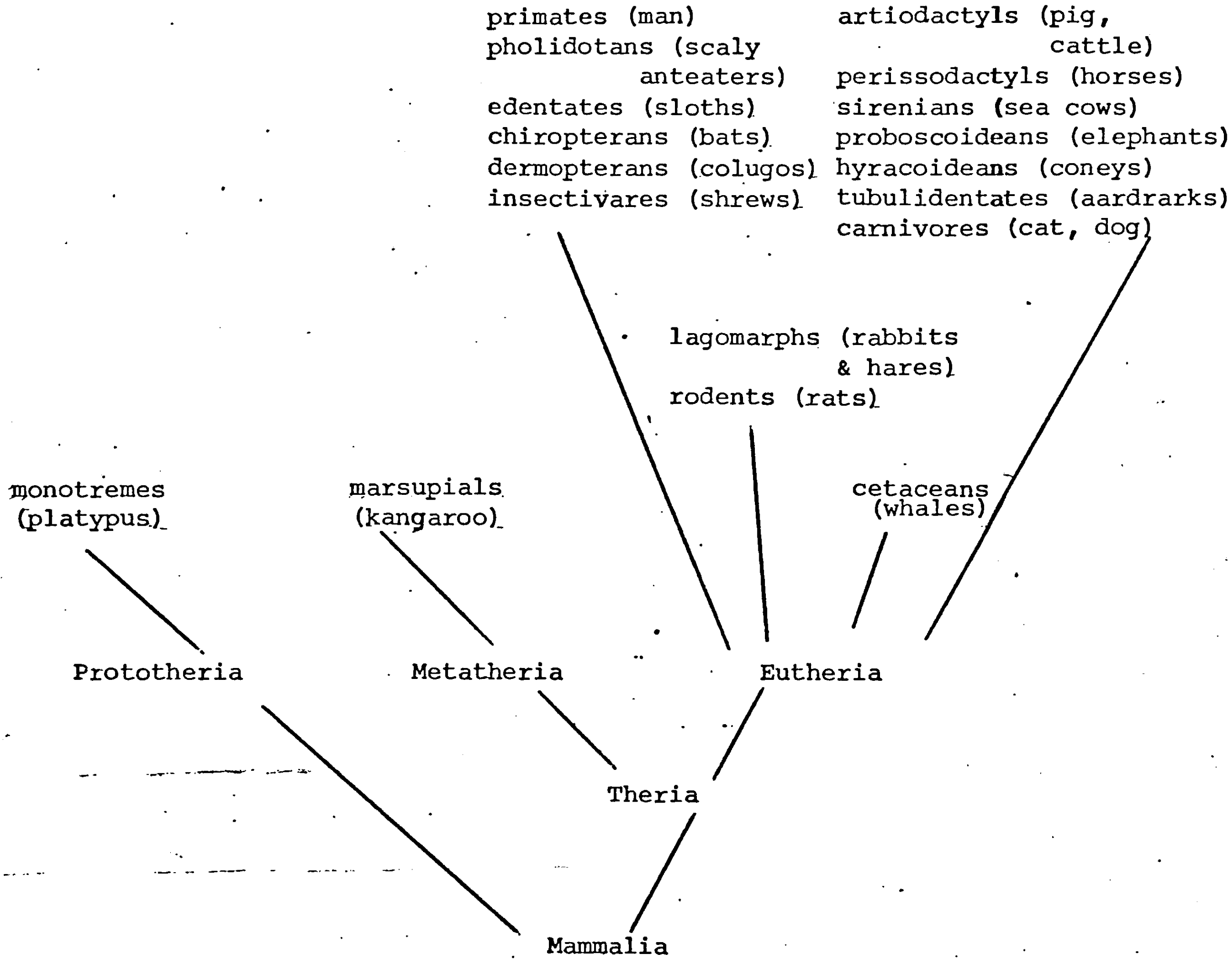
Notes

1) Ellerman (1941) states this group is closely allied to Peromyscus

2) Ellerman (1941) groups these together as the Palaeartic hamsters

3) Ellerman (1941) states that this group may be allied to the Cricetus series.

b. Simple classification of the mammalian class



c. Simple classification of Rodentia, with examples of 'better known' genera

Order RODENTIA
Sub-order SCIUROMORPHA

Sciurus (squirrel); Marmota (marmot, woodchuck); Tamias (chipmunk); Castor (beaver); Aplodontia (sewellel, mountain beaver); Xerus (African ground squirrel); Citellus (American ground squirrel, gopher); Glaucomys (American flying squirrel); Geomys (pocket gopher); Anomalurus (scale-tailed flying squirrel); Pedetes (jumping hare)

Sub-order MYOMORPHA

Peromyscus (deer mouse); Sigmodon (cotton rat); Cricetus (hamster); Mesocricetus (golden hamster); Mystromys (white-tailed rat); Lophiomys (maned rat); Lemmus (lemming); Microtus (vole); Clethrionomys (bank vole); Arvicola (water vole); Ondatra (muskrat); Rattus (rat); Rattus (Mastomys[1]) (multimammate rat, coucha rat); Apodemus (wood mouse); Mus (house mouse); Gerbillus (gerbil); Meriones (jird); Spalax (mole rat); Glis Muscardinus (dormice); Zapus (jumping mouse); Jaculus (jerboa)

Sub-order HYSTRICOMORPHA

Cavia (guinea pig); Hydrochoerus (capybara); Chinchilla (chinchilla); Myocastor (coypu); Hystrix (porcupine); Cuniculus (paca)

[1] Mastomys is a sub-genus of Rattus

d. Detail of the genus Mesocricetus, Nehring -

List of named forms;

1. Mesocricetus auratus auratus, Waterhouse
2. Mesocricetus auratus brandti, Nehring
3. Mesocricetus raddei raddei, Nehring
4. Mesocricetus raddei nigriculus, Nehring
5. Mesocricetus raddei avaricus, Ognev and Heptner
6. Mesocricetus newtoni, Nehring

APPENDIX F: Raw Data Tables

TABLES

1. Body weights for mature animals in pilot study
2. Open-field scores for mature animals in pilot study
3. Collective data for animals used in B-L condition
4. " " " " " " L-L "
5. " " " " " " L-D "
6. " " " " " " B-D "
7. " " " " " " H_{0-21} "
8. " " " " " " H_{5-21} "
9. " " " " " " H_{0-4} "
10. " " " " " " NH "

1. WEIGHTS

Condition	Sex	Weight (day x)(gms)	Weight (day x + 24)	Weight (day x + 45)
CONTROL	M	100	109	112
	M	117	120	118
	M	109	118	118
	F	98	103	101
	F	106	113	118
	F	99	103	106
	F	109	109	109
EXPERIMENTAL	M	95	102	112
	M	116	120	130
	F	124	132	144
	F	98	103	127

2. Open-Field Scores

PRE-ENRICHMENT

		AMBULATION			
CONDITION	EMERGENCE TIME (secs)	INNER SECTIONS	OUTER SECTIONS	TOTAL SECTIONS	REARING
CONTROL M	4	1	42	43	9
n = 3	3	3	57	60	5
	8	0	37	37	7
F	2	0	51	51	5
n = 4	2	1	39	40	3
	6	0	37	37	5
	4	0	21	21	2
EXPERIMENTAL M	4	3	41	44	10
n = 2	7	2	16	18	1
F	4	9	34	43	0
n = 2	3	3	65	68	12

POST-ENRICHMENT

		AMBULATION			
CONDITION	EMERGENCE TIME (secs)	INNER SECTIONS	OUTER SECTIONS	TOTAL SECTIONS	REARING
CONTROL M	4	3	24	27	0
n = 3	2	3	37	40	4
	5	0	39	39	4
F	2	7	35	42	2
n = 4	1	0	25	25	2
	16	0	8	8	3
	5	3	11	14	3
EXPERIMENTAL M	2	3	36	39	12
n = 2	3	4	50	54	13
F	2	6	38	44	7
n = 2	2	12	59	71	9

TABLE 3:

B-L Condition		Body weight (gms): 21	42	55	63	84	90 (+)days	O/F Ambulation: day 1	2	3	4	O/F Rearing: day 1	2	3	4	Novelty Testing: Ambulation	RT_1	RT_2	T/O_1	T/O_2 (secs)	Disc. Learn. Correct Responses: day 1	2	3	4	Disc. Learn. Trial Time: (secs) day 1	2	3	4	Brain weight (gms x 10^2)	Adrenal gland weight (gms x 10^3)	Cortisol level (nmols/L)
L 175	M/-	38	94				107	41	27	34	52	11	11	11	10	19	3	3	16	8	11	18	20	20	51	48	29	28			
	M/LS	38	104				105	60	37	41	39	24	21	16	20	15	10	5	8	4	15	20	20	20	57	26	29	30			
	M/T	38	100				108	42	32	23	36	19	14	7	10	13	7	32	8	27	11	14	19	20	42	49	44	42			
	F/-	38	99				138	69	49	51	49	29	25	23	22	11	3	11	5	22									83	16	0
	F/RS	38	104				154	59	39	40	35	26	12	18	10	22	2	48	7	10									79	15	8
	F/T	38	86				130	63	41	56	33	29	13	19	13	28	2	22	10	12									77	17	0
L 176	M/LS	39	93				98	30	27	26	38	3	3	2	1	13	1	78	10	6									88	28	52
	-	39	88				101	27	28	26	22	9	3	3	4	16	2	58	11	14									76	23	15
	T	39	99				106	42	43	43	19	18	26	15	4	11	3	2	18	22									72	25	52
	RS	39	98				100	40	45	28	39	23	32	8	24	21	1	14	13	11									82	19	24
	B	39	98				93	35	21	24	25	9	3	7	6	13	21	5	35	21									80	17	28
	F/RS	39	93				109	41	34	25	26	12	15	19	10	17	1	3	7	8									78	18	15
	T	39	97				114	58	45	38	40	16	12	10	16	19	2	1	10	8									88	15	0
	-	39	92				106	51	12	19	33	12	3	2	5	17	3	24	6	16									81	14	20
L 188	M/G	39	101	108			116	34	19	38	16	14	6	9	3	11	1	17	19	13											
	TG	39	86	91			100	20	35	27	28	3	3	1	0	8	3	13	12	11											
	Cr	39	105	115			130	18	29	15	21	6	3	4	11	9	1	8	20	19											
	TCr	39	111	117			125	19	32	20	33	5	9	3	14	11	8	76	14	18											
	F/T	39	93	103			130	57	71	44	47	18	14	14	9	19	15	3	40	12											
	B	39	100	111			139	37	31	39	10	10	11	6	2	16	6	28	18	19											
	-	39	110	123			150	31	13	19	13	2	0	2	2	18	2	1	26	19											

TABLE 4:

L-L Condition		Body weight (gms): 21 "	42 "	55 "	63 "	84 "	90 (+) days	O/F Ambulation: day 1	2	3	4	O/F Rearing: day 1	2	3	4	Novelty Testing: Ambulation	RT_1 "	RT_2 "	T/O_1 "	T/O_2 (secs)	Disc. Learn. Correct Responses: day 1	2	3	4	Disc. Learn. Trial Time: (secs) day 1	2	3	4	Brain weight (gms x 10^2)	Adrenal gland weight (gms x 10^3)	Cortisol level (nmols/L)
L 179	M/T	49	101	99			105	58	58	46	71	20	23	30	30	14	14	30	22	17									76	16	10
	B	49	103	103			108	61	34	47	46	27	14	27	19	13	1	9	11	27									75	22	13
	RS	49	100	99			103	46	13	17	15	17	1	2	0	7	5	18	32	15									75	20	40
	-	49	95	96			101	25	22	20	26	12	8	6	7	10	2	112	10	12									76	23	58
	LS	49	98	96			106	64	47	49	53	31	31	31	33	19	2	5	9	13									77	18	3
	F/T	49	111	-			110	57	28	47	51	18	21	25	29														81	14	15
	LS	49	107	108			124	28	23	19	20	6	5	7	5	20	12	96	19	10									76	15	63
	-	49	105	105			103	48	29	47	55	27	16	30	29	15	1	82	5	6									81	16	13
	RS	49	101	103			115	44	35	30	44	15	11	8	2	16	10	18	43	19									78	10	10
L 180	M/B	41	92	93		104		55	33	19	22	6	9	13	10	15	40	15	17	4									76	19	30
	-	41	106	108		119		29	6	16	19	3	4	5	5	13	1	58	22	15									92	23	162
	F/B	41	90	93			136	67	42	22	22	10	2	4	2	24	1	2	13	27											
	-	41	82	87			127	59	24	23	22	15	9	2	5	19	1	2	22	14											
L 191	M/-	35	106	113			119	50	16	3	19	35	4	0	1	11	4	19	49	14	8	18	19	20	227	210	146	102			
	B	35	92	95			93	63	24	26	27	17	5	6	6	13	27	2	44	5											
	T	35	108	113			115	64	50	49	41	27	21	31	29	16	3	6	27	27	6	14	19	20	252	178	33	64			
	RS	35	112	125			128	46	40	28	34	25	27	8	17	13	11	120	15	0	11	14	18	19	137	101	41	51			
	F/-	35	93	104			128	67	61	78	58	29	37	40	28	17	3	1	71	16											
	B	35	102	121			158	47	25	23	9	6	13	5	1	25	1	26	32	13											
	T	35	95	105			147	63	38	24	31	31	27	14	22	20	16	41	30	31											
	F/T	35	90	105			141	73	53	45	42	44	32	10	20	17	1	7	33	18											
	LS	35	96	109			126	63	51	51	29	34	26	27	15	32	13	3	47	29											
	B	35	99	114			138	69	72	50	78	33	31	18	54	21	27	3	63	21											
	-	35	106	120			149	73	66	54	24	26	23	28	4	21	2	5	38	38											
	RS	35	101	118			145	47	34	17	8	24	15	4	6	19	5	9	51	55											
	H	35	99	117			147	87	40	54	59	29	35	25	35	29	3	1	42	20											

TABLE 5:

L-D Condition		Body weight (gms)						O/F Ambulation: day				O/F Rearing: day				Novelty Testing: Ambulation	RT1 "	RT2 "	T/O1 "	T/O2 (secs)	Disc. Learn. Correct Responses: day				Disc. Learn. Trial Time: day (secs)				Brain weight (gms x 10^2)	Adrenal gland weight (gms x 10^3)	Cortisol level (nmols/L)
		21 "	42 "	55 "	63 "	84 "	90 (+)days	1	2	3	4	1	2	3	4						1	2	3	4	1	2	3	4			
L 177	M/LS	45	104	103		121		63	18	19	15	22	7	10	5	11	3	7	6	7									77	22	0
	T	45	109	109			126	50	20	43	29	17	3	6	4	20	1	6	5	10	13	17	20	20	71	35	40	30			
	-	45	100	108			118	56	34	17	25	15	16	9	13	26	4	10	4	3	15	18	20	20	66	33	26	28			
	RS	45	100	108		106		84	27	47	32	15	3	7	4	11	2	27	14	10									74	18	118
	B	45	102	106			112	21	14	12	19	7	2	2	4	13	1	14	16	9	16	20	20	20	53	29	15	18			
	F/T	45	107	110		153		60	38	35	23	20	23	26	12	18	2	2	6	5									82	16	0
	-	45	106	112		156		52	32	39	22	20	26	19	6	24	4	92	11	3									82	15	7
	B	45	117	126		156		72	28	47	41	25	24	24	17	31	3	51	9	5									83	15	0
L 190	M/T	26	81	94			112	52	26	17	23	22	4	6	15	11	4	5	17	9											
	-	26	83	97			120	32	15	18	5	2	0	1	0	10	12	19	6	33									61	16	5
	B	26	82	90			127	31	13	16	24	9	4	2	6	18	7	2	8	8									69	25	74
	F/LS	26	85	98			-	73	49	48	25	30	11	14	9	20	25	2	15	16											
	-	26	77	103			125	42	26	34	13	15	8	16	5	30	2	22	15	8											
	F/T	26	73	79			102	34	16	9	15	3	5	1	11	17	4	20	11	12											
	RS	26	76	86			103	70	51	42	27	12	16	14	13	20	2	114	27	2											
	-(e)	26	83	100		106	156	65	46	36	25	12	6	2	2	23	6	3	26	17									63	21	13
	B(e)	26	69	87		127	147	50	39	17	29	5	6	5	8	19	2	4	14	13									67	16	8
L 194	M/-	44	104		122		161	66	41	46	54	29	19	26	28	18	3	29	7	6											
	B	44	103		112		152	67	49	54	77	30	30	27	45	28	23	9	4	2											
	RS	44	109		136		145	60	24	25	48	29	6	11	12	20	3	32	3	11									82	19	0
	LS	44	94		105		153	56	27	37	32	36	23	16	25	19	4	3	10	4											
	T	44	105		113			72	50	31	51	23	20	23	16	25	3	120	4	0											
	F/LS	44	100		131			47	56	27	25	19	33	12	10	13	1	94	8	7											
	T	44	99		121			86	75	51	52	36	50	22	29	25	1	3	2	14											
	RS	44	105		136			25	22	39	18	10	7	17	7	34	2	6	12	13											
	-	44	95		118			80	44	28	46	31	26	10	25	20	2	17	8	8											
	F/-	44	95		104		118	70	21	13	23	20	11	4	11	14	3	25	10	8											

TABLE 6:

B-D Condition		Body weight (gms) 21 days	42 "	55 "	63 "	84 "	90 (+) days	O/F Ambulation: 1	2	3	day 4	O/F Rearing: 1	2	3	day 4	Novelty Testing: Ambulation	RT_1 "	RT_2 "	T/O_1 "	T/O_2 (secs)	Disc. Learn. Correct Responses: 1	2	3	day 4	Disc. Learn. Trial Time: (secs) 1	2	3	day 4	Brain weight (gms x 10^2)	Adrenal gland weight (gms x 10^3)	Cortisol level (nmols/L)
L 189	M/T	47	112	126			131	46	26	24	18	11	4	6	0	9	28	5	4	2	7	14	19	19	104	92	46	46			
	B	47	104	116			135	36	24	30	21	8	8	5	3	17	5	3	10	16	13	17	18	20	93	65	49	31			
	-	47	118	127			146	57	28	21	11	16	11	4	4	10	5	24	6	15	12	18	19	20	79	61	32	41			
	F/-	47	108	124		159	161	46	26	15	23	24	5	4	8	23	2	87	7	23									77	13	3
L 193	M/-	45	104		111		116	53	44	31	50	21	11	9	15	28	3	3	6	2									71	19	8
	T	45	104		111		118	39	44	52	28	40	31	35	16	14	28	2	6	2									68	25	0
	F/B	45	101		126		156	37	34	51	23	22	24	33	20	34	3	2	3	8									82	22	28
	-	45	107		129		185	67	19	39	31	24	7	14	16	26	1	13	4	8									81	16	0
	H	45	106		136			55	41	27	14	13	9	4	3	34	1	12	9	7											
	LS	45	109		130			57	31	33	33	13	12	15	8	27	3	12	7	13											
	RS	45	112		134			20	14	18	19	2	0	0	1	13	10	71	8	9											
	T	45	100		121		162	52	27	34	19	17	7	20	5	27	13	4	8	10									85	13	0
L 207	M/-	41	81	101			129	38	19	27	25	6	8	6	5	20	1	2	17	9											
	B	41	81	107			144	45	28	30	3	18	14	12	5	16	2	4	65	8											
	F/T	41	73	90			131	51	29	25	29	23	16	14	15	18	5	9	5	10											
	B	41	81	98			138	48	18	9	7	18	21	9	4	17	2	42	12	18											
	LS	41	102	119			174	49	41	47	36	24	34	26	20	22	2	44	14	5											
	RS	41	84	112			157	66	51	37	34	21	21	18	10	17	2	11	45	11											
	H	41	83	107			150	30	10	21	12	12	7	3	4	19	2	57	36	12											
	-	41	85	113			169	44	34	44	28	14	21	21	12	25	2	18	10	17											

TABLE 7:

H_{0-21}	Condition	Body weight (gms) 21 "	42 "	55 "	63 "	84 "	90(+)days	O/F Ambulation: day 1	2	3	4	O/F Rearing: day 1	2	3	4	Novelty Testing: Ambulation	RT_1 "	RT_2 "	T/O_1 "	T/O_2 (secs)	Disc. Learn. Correct Responses: 1	2	3	day 4	Disc. Learn. Trial Time: (secs) 1	2	3	day 4	Brain weight (gms x 10^2)	Adrenal gland weight (gms x 10^3)	Cortisol level (nmols/L)
L 184	M/T	22	64	71		76		11	9	12	19	2	1	2	0	11	21	14	7	14									70	19	24
	LS	22	75	85		97		4	5	1	3	1	2	0	0	6	43	7	9	8									61	19	18
	-	22	72	79		86		19	4	6	4	6	1	0	1	8	120	29	0	9									64	19	38
	B	22	67	72		80		21	12	17	25	2	2	0	1	13	4	6	5	23									69	21	33
	M/-	22	52	62			84	12	6	12	3	2	0	1	0	4	116	3	4	1	13	16	20	18	99	74	71	101			
	T	22	61	67			81	12	13	19	4	1	1	1	4	7	71	120	2	0	11	13	18	19	140	70	56	53			
	B	22	64	69			79	19	9	24	11	1	0	1	4	10	51	93	12	14	13	14	19	18	147	76	53	76			
	F/A(-)	22	65	70		91		22	18	25	18	7	5	5	4	22	1	15	11	7									75	12	0
	B(T)	22	68	77		68		77	80	61	48	37	42	39	31	17	3	16	7	19									73	87	0
L 185	M/-	39	88	93			105	31	37	20	18	6	4	4	2	15	19	23	12	15											
	LS	39	89	93		98		33	32	13	17	3	0	2	2	28	7	1	7	3									79	20	88
	RS	39	96	105			128	19	24	27	6	1	1	4	6	13	5	12	29	9											
	H	39	86	91			103	28	40	18	30	5	4	6	8																
	B	39	90	98			107	12	15	6	15	1	0	1	0	18	1	16	10	21											
	T	39	87	94			108	15	24	18	8	1	2	3	6	6	2	7	7	14											
	F/LS	39	91	106			147	33	27	23	6	9	2	7	3	19	5	2	5	6											
	RS	39	78	94			143	35	25	27	28	11	3	11	2	19	2	2	7	14											
	T	39	91	103			145	22	32	21	27	3	1	1	1	18	3	25	7	8											
	-	39	89	103			141	24	10	27	5	2	2	2	1	17	1	92	17	8											
	B	39	83	95			125	56	33	9	40	22	18	9	7	25	8	12	9	5											
L 186	M/B	36	70	77	88			41	33	14	27	12	7	3	3	5	2	7	10	7									76	16	105
	-	36	75	80	96			22	8	18	8	5	1	2	1	7	55	7	16	17									73	17	35
	Cr	36	70	73	86			25	26	16	22	9	5	3	11	10	45	21	7	21									-	15	53
	F/-G	36	79	79	100			43	50	48	44	26	26	26	20	38	29	21	11	13									78	14	63
	TG	36	71	79	93			56	65	56	56	22	38	34	34	36	9	15	8	12									75	14	7
	T	36	74	79	103			77	64	54	62	31	32	25	35	31	2	44	10	11									77	12	23
	LS	36	69	77	98			41	29	24	20	7	10	1	2	22	2	19	24	52									78	14	0
	B	36	66	74	105			58	38	34	41	21	23	5	12	27	1	32	18	12									76	12	30
	-	36	67	79	107			37	12	29	25	12	4	4	2	22	11	52	21	15									76	14	0

TABLE 8:

H_{5-21}	Condition	Body weight (gms) 21 "	42 "	55 "	63 "	90 (+) days / 84 "	O/F Ambulation: 1	2	3	day 4	O/F Rearing: 1	2	3	day 4	Novelty Testing: Ambulation	RT_1 "	RT_2 "	T/O_1 "	T/O_2 (secs)	Disc. Learn. Correct Responses: 1	2	3	day 4	Disc. Learn Trial Time: (secs) 1	2	3	day 4	Brain weight (gms x 10^2)	Adrenal gland weight (gms x 10^3)	Cortisol level (nmols/L)
L 181	M/-(Sh)	39	95	111		137	100	38	33	8	6	8	12	9	12	3	7	27	74	8	13	17	18	108	83	70	63			
	T	39	74	76		91	16	13	2	2	3	2	2	1	5	7	2	15	11	5	10	19	19	184	111	72	81			
	B(Sh)	39	85	90		112	15	2	9	9	1	0	0	0	5	32	68	24	19	7	14	18	19	237	101	50	56			
	F/-G	39	79	86	95		62	56	48	44	35	30	17	21	26	29	3	21	3											
	T	39	80	92	103		29	20	22	20	5	4	2	5	25	2	51	7	7									68	18	0
	B	39	86	103	113		46	16	17	15	13	5	4	3	9	3	54	12	10									75	17	23
L 187	M/B	38	90	98	115		20	12	39	17	3	2	1	0	18	4	6	16	18									76	21	15
	LS	38	85	95	109		7	4	11	8	2	1	1	0	13	1	22	11	12									75	20	93
	T	38	83	88	101		20	32	19	21	3	3	4	0	13	9	19	10	20									78	25	18
	-	38	89	97	106		20	21	22	31	5	5	7	5	19	4	7	12	18									81	17	123
	RS	38	93	101	111		19	41	15	6	4	7	6	2	15	2	6	9	24									79	25	75
	F/nose	38	86	93		125	16	21	7	6	1	0	0	1	14	1	2	15	11											
	-	38	75	86		119	15	5	5	5	2	1	1	1	9	37	13	15	13											
	T	38	73	78		107	43	43	59	53	7	13	25	27	22	1	35	9	17											
	B	38	91	106		132	28	19	17	25	1	1	0	0	21	5	9	5	15											
L 195	M/LS	28	85		97	168	26	38	41	27	13	10	5	6	16	3	2	26	20											
	RS	28	73		85	147	10	28	19	20	3	0	1	0	9	3	21	12	11											
	-	28	77		104	173	40	29	49	24	10	5	6	1	5	2	4	23	12											
	T	28	83		90	150	25	30	27	18	10	1	4	4	14	2	5	4	14											
	F/LS	28	90		115	162	21	4	13	29	6	7	1	1	13	11	10	34	9											
	T	28	76		93	154	60	11	16	32	40	12	6	10	18	3	120	15	0									81	21	0
	-	28	75		95	140	44	20	11	30	21	13	7	8	17	3	2	40	20									78	17	0
	B	28	78		96	144	54	32	23	29	26	22	43	29	18	2	2	17	12											
	RS	28	92		96	139	22	24	17	22	5	2	14	5	17	5	18	18	15									73	11	13
	H	28	78		93	146	61	31	21	18	26	23	12	16	19	2	57	27	19											

TABLE 9:

H$_{0-4}$	Condition	Body weight (gms) 21 days	42 "	55 "	63 "	84 "	90(+) days	O/F Ambulation: day 1	2	3	4	O/F Rearing: day 1	2	3	4	Novelty Testing: Ambulation	RT$_1$ "	RT$_2$ "	T/O$_1$ "	T/O$_2$ (secs)	Disc. Learn. Correct Responses: day 1	2	3	4	Disc. Learn. Trial Time: day (secs) 1	2	3	4	Brain weight (gms x 10^2)	Adrenal gland weight(gms x 10^3)	Cortisol level (nmols/L)
L 198	M/T	27		78			93	22	22	56	17	6	5	5	0	16	1	26	8	13	14	18	19	19	254	180	52	42			
	B	27		79			101	9	6	27	9	1	0	1	2	14	10	120	18	0											
	LS	27		76			91	10	3	10	5	2	0	0	0	9	3	32	8	9	9	15	18	17	203	91	64	63			
	RS	27		80			110	25	25	35	43	3	2	6	2	25	2	48	6	14	10	18	20	20	182	84	65	50			
	-	27		72			82	37	7	19	17	13	6	6	3	9	23	21	17	17											
	F/T	27		78			105	19	9	20	15	3	0	0	1	15	3	20	9	8									72	15	5
	B	27		67			143	31	28	23	34	3	2	1	8	16	14	8	10	9									82	15	0
	LS	27		81			103	27	26	28	16	10	7	2	2	30	2	2	12	23									75	14	5
	RS	27		68			125	12	23	7	8	3	3	0	1	28	2	13	12	13									78	25	0
	2B	27		80			129	15	18	14	20	4	0	0	1	6	11	92	10	16									72	17	18
	H	27		78			109	59	51	32	14	33	44	16	14	26	2	69	22	13											
	-	27		71			100	22	30	15	18	7	7	5	2	17	2	12	9	28											
L 205	M/-Cr	31	87	90			114	33	36	34	37	9	21	19	21	29	1	5	16	15									81	19	82
	-G	31	99	106			121	7	22	20	20	6	18	8	12	17	2	98	13	5									77	22	28
	B	31	83	91			101	28	17	43	31	13	9	20	22	13	1	35	18	26									81	17	57
	T	31	85	95			96	73	24	20	17	38	16	19	19	23	3	7	21	14									76	19	155
	RS	31	78	93			105	22	31	26	17	7	15	9	4	20	1	5	10	9									80	24	90
	F/B	31	81	95			137	49	22	17	24	21	9	12	7	17	2	5	15	20											
	T	31	88	107			167	45	26	56	37	19	16	29	26	21	2	80	20	5											
	LS	31	72	95			138	57	46	73	39	35	18	30	19	31	10	93	24	25											
	RS	31	81	87			126	99	70	77	78	37	16	30	26	51	1	3	22	13											
	-	31	86	105			143	31	34	27	16	19	13	15	12	20	5	10	33	26											
	Pie	31	80	90			140	61	50	32	37	35	36	31	31	17	19	120	27	0											
L 206	M/B	24	80	92			112	28	28	19	20	7	9	6	4	8	12	38	23	11											
	T	24	92	105			116	37	33	14	22	20	21	8	16	15	3	105	17	15											
	-	24	78	87			94	58	19	9	21	18	5	11	9	12	4	66	10	8											

TABLE 10:

NH Condition

			Body weight (gms): 21 "	42 "	55 "	63 "	84 "	90 (+) days	O/F Ambulation day 1	2	3	4	O/F Rearing: day 1	2	3	4	Novelty Testing: Ambulation	RT$_1$ "	RT$_2$ "	T/O$_1$ "	T/O$_2$ (secs)	Disc. Learn. Correct Responses:day 1	2	3	4	Disc. Learn. Trial Time:(secs) day 1	2	3	4	Brain weight (gms x 10^2)	Adrenal gland weight (gms x 10^3)	Cortisol level (nmols/L)
L 199	M/Ci		36		92			131	57	40	32	39	15	7	1	3	11	4	24	36	50	8	13	18	20	218	119	65	47			
	Cr		36		77			116	32	27	28	28	3	6	5	5	9	11	2	12	14											
	-G		36		80			147	29	19	14	21	3	2	1	0	7	36	25	7	5	10	16	14	20	234	112	76	49			
	T(Sh)		36		80			151	36	21	22	22	7	5	3	6	17	8	5	51	107	13	11	17	17	200	102	109	86			
	F/G		36		89			126	81	7	31	44	17	4	13	18	26	1	8	26	20									82	18	38
	B(Sh)	BEC	36		84			141	58	33	28	25	23	13	10	5	33	1	35	49	21											
	T		36		93			148	70	53	47	32	14	21	17	11	27	3	6	40	25											
	-(Sh)		36		94			160	64	56	51	55	19	26	19	18	21	3	64	10	25									84	18	0
	-(Sh)	REC	36		99			134	97	30	21	39	18	4	8	13	22	4	4	16	29											
	T		36		89			126	50	35	29	9	22	6	6	2	16	32	26	12	36									-	14	-
L 200	M/-		33		93			141	33	9	13	24	6	0	1	1	11	1	103	16	37									76	27	103
	B		33		90			127	34	12	13	5	4	7	1	0	7	2	2	16	25									78	20	10
	F/-		33		97			147	40	12	7	8	6	6	1	0	24	2	19	9	27											
	B		33		87			116	17	5	8	4	3	2	2	2	14	3	120	13	0											
	T		33		92			131	23	9	10	11	9	2	2	1	25	1	7	41	16											
	LS		33		98			147	44	17	31	23	14	10	2	16	35	11	13	13	14											
	RS		33		88			115	39	10	13	21	7	10	2	1	21	3	39	11	20											
	H		33		97			147	24	10	14	22	9	5	1	0	17	15	6	14	8											
	F/-	ALB	33		91			137	85	37	20	16	21	9	4	7	7	23	2	38	26									80	14	0
	B		33		94			151	42	13	31	16	12	3	0	0	5	22	18	8	29									80	15	73
	T		33		107			160	43	28	32	33	20	12	6	9	13	4	4	19	21									80	16	23

Litter Means and Individual Results used in Analyses
(Tables A - N).

A Litter means used in analyses of variance for body wt. in preweaning conditions (gms.)

Male	Condition	3 wks.	6 wks.	9 wks.	12 wks.
	B-L	38	82	100	102
		39	78	96	99
		39	69	92	101
	L-L	49	83	100	104
		41	81	104	110
		35	94	112	113
	0-21	22	63	75	83
		39	90	99	104
		36	72	81	89
Female	B-L	38	79	108	129
		39	77	99	107
		39	66	87	94
	L-L	49	87	107	112
		41	72	95	106
		35	85	118	133
	0-21	22	64	75	78
		39	86	106	120
		36	71	85	98

B Litter means used in analyses of variance for body weight in environmental (pre and post-weaning) conditions (gms.)

Males	Condition	3 wks.	6 wks.
	B-L	38	82
		39	78
		39	69
	L-L	49	83
		41	81
		35	94
	L-D	45	86
		26	74
		44	93
	B-D	41	79
		47	101
		45	95
Females	B-L	38	79
		39	77
		39	66
	L-L	49	87
		41	72
		35	85
	L-D	45	90
		26	69
		44	90
	B-D	47	98
		45	96
		41	83

C Litter means used in analyses of variance for body weight in handling conditions (gms.)

	Condition	21 days	55 days	90 days
Males	L-L	48	99	105
		41	101	112
		35	112	114
	H_{0-21}	22	72	81
		39	97	105
		36	77	90
	H_{5-21}	39	92	105
		38	96	108
		28	87	104
	H_{0-4}	27	77	85
		31	91	107
		24	89	103
	NH	36	82	103
		33	92	113
		$\bar{x}$	$\bar{x}$	$\bar{x}$
Females	L-L	48	105	113
		41	90	112
		35	113	142
	H_{0-21}	22	74	80
		39	99	121
		36	78	101
	H_{5-21}	39	94	104
		38	91	110
		28	89	117
	H_{0-4}	27	75	96
		31	90	126
		24	88	118
	NH	36	91	116
		33	95	121
		$\bar{x}$	$\bar{x}$	$\bar{x}$

D Ambulation (Contd.)

Condition	Sex	Days 1	2	3	4
H_{0-21}	Male	14	8	13	10
		23	29	17	16
		29	22	16	19
	Female	50	49	43	33
		34	25	21	21
		52	43	41	41
H_{5-21}	Male	44	18	15	6
		17	22	21	17
		25	31	34	22
	Female	46	31	29	26
		26	22	22	22
		44	20	17	27
H_{0-4}	Male	33	26	29	24
		41	27	14	21
		21	13	29	18
	Female	57	41	47	39
		26	26	20	18
		44	35	35	30
NH	Male	39	27	24	28
		34	10	13	15
		$\bar{x}$	$\bar{x}$	$\bar{x}$	$\bar{x}$
	Female	70	36	35	34
		40	16	18	17
		$\bar{x}$	$\bar{x}$	$\bar{x}$	$\bar{x}$

D Litter means used in analyses on open-field ambulation (sections entered)

Condition	Sex	Days 1	2	3	4
B-L	Male	48	32	33	42
		35	33	29	29
		23	29	25	25
	Female	64	43	49	39
		50	30	27	33
		42	38	34	13
L-L	Male	51	35	36	42
		42	20	18	21
		56	33	27	30
	Female	44	29	36	43
		63	33	23	22
		65	49	44	37
L-D	Male	55	23	28	24
		38	18	17	17
		64	38	39	52
	Female	61	33	40	29
		56	38	31	22
		62	44	32	33
B-D	Male	46	26	25	17
		46	44	42	39
		42	24	29	14
	Female	46	26	15	23
		48	28	34	23
		48	31	31	24

E Litter means used in analyses on open-field rearing

Condition	Sex	Days 1	2	3	4
B-L	Male	18	15	11	13
		12	13	7	8
		7	5	4	7
	Female	28	17	20	15
		13	10	10	10
		10	8	7	4
L-L	Male	21	15	19	18
		5	7	9	8
		26	14	11	13
	Female	17	13	18	16
		13	6	3	4
		28	27	19	21
L-D	Male	15	6	7	6
		11	3	3	7
		29	20	21	25
	Female	22	24	23	12
		13	9	9	6
		23	25	13	16
B-D	Male	12	8	5	2
		31	21	22	16
		12	11	9	5
	Female	24	5	4	8
		15	10	14	9
		19	20	15	11

E Rearing (Contd.)

Condition	Sex	Days 1	2	3	4
H_{0-21}	Male	2	1	1	1
		3	2	3	4
		9	4	3	5
	Female	22	24	21	18
		9	5	6	3
		20	22	16	18
H_{5-21}	Male	3	3	5	3
		3	7	4	1
		9	4	4	3
	Female	18	13	8	10
		3	4	7	8
		21	13	12	12
H_{0-4}	Male	15	16	15	16
		15	12	8	10
		5	3	6	1
	Female	28	18	25	20
		9	9	3	4
		21	15	16	14
NH	Male	7	5	3	4
		5	3	1	1
		$\bar{x}$	$\bar{x}$	$\bar{x}$	$\bar{x}$
	Female	19	12	12	11
		11	7	2	4
		$\bar{x}$	$\bar{x}$	$\bar{x}$	$\bar{x}$

F Litter means used in analyses of latency to respond to novel objects in novelty test (seconds)

Condition	Sex	R/T$_1$	R/T$_2$	Condition	Sex	R/T$_1$	R/T$_2$
B-L	M	3	29	H_{0-21}	M	61	39
		7	13			7	12
		6	31			34	12
	F	8	11		F	2	16
		2	27			4	27
		2	9			9	31
L-L	M	11	37	H_{5-21}	M	14	26
		5	35			4	12
		20	37			3	8
	F	8	11		F	4	35
		8	65			11	36
		1	2			11	15
L-D	M	7	39	H_{0-4}	M	8	49
		8	27			2	30
		2	13			6	70
	F	2	29		F	5	31
		7	24			7	52
		3	48			$\bar{x}$	$\bar{x}$
B-D	M	16	3	NH	M	15	14
		13	11			2	53
		2	3			$\bar{x}$	$\bar{x}$
	F	5	19		F	7	24
		2	87			9	25
		3	30			$\bar{x}$	$\bar{x}$

G Litter means used in analyses of total time on objects in novelty test (seconds)

Condition	Sex	T/O_1	T/O_2	Condition	Sex	T/O_1	T/O_2
B-L	M	14	15	H_{0-21}	M	6	10
		11	13			13	12
		17	15			11	15
	F	28	17		F	9	13
		7	15			9	8
		8	11			15	19
L-L	M	34	12	H_{5-21}	M	22	35
		17	16			12	18
		20	10			16	14
	F	45	27		F	25	13
		22	12			13	7
		18	21			11	14
L-D	M	6	5	H_{0-4}	M	11	11
		10	17			16	14
		9	8			17	11
	F	8	10		F	12	16
		17	11			24	15
		9	4			21	15
B-D	M	6	4	NH	M	27	44
		7	33			16	21
		41	9			$\bar{x}$	$\bar{x}$
	F	7	9		F	26	26
		7	23			18	18
		20	11			$\bar{x}$	$\bar{x}$

H Litter means used in analyses of novelty testing ambulation (sections entered)

Rearing Conditions	B-L	L-L	L-D	B-D
Males	16	13	16	12
	15	14	13	12
	10	13	22	18
Females	20	17	24	23
	18	22	22	27
	18	22	21	20

Handling Conditions	H_{0-21}	H_{5-21}	H_{0-4}	NH
Males	9	7	15	11
	16	16	20	9
	7	11	12	$\bar{x}$
Females	20	17	20	24
	20	20	28	18
	28	7	24	$\bar{x}$

I Individual results for males (3/condition) used in discrimination learning trials (number of correct responses)

Condition	Trials 1	2	3	4
B-L	11	14	20	20
	15	20	19	20
	11	18	20	20
L-L	6	14	19	20
	11	14	18	19
	8	18	19	20
L-D	15	18	20	20
	16	20	20	20
	13	17	20	20
B-D	12	17	19	19
	13	14	19	20
	7	18	18	20
H_{0-21}	13	14	19	18
	13	16	18	19
	11	13	20	18
H_{5-21}	5	10	18	19
	7	14	19	18
	8	13	17	19
H_{0-4}	14	18	19	19
	10	15	20	20
	9	18	18	17
NH	10	16	18	17
	13	13	17	20
	8	11	14	20

J Individual results for males (3/condition) used in discrimination learning trials (time taken for trial in seconds)

Condition	Trials 1	2	3	4
B-L	51	48	29	28
	42	49	44	42
	57	26	29	30
L-L	252	178	33	64
	137	101	41	51
	227	210	146	102
L-D	66	33	26	28
	53	29	15	18
	71	35	40	30
B-D	79	61	32	41
	93	65	49	31
	104	92	46	46
H_{0-21}	147	76	53	76
	99	74	71	101
	140	70	56	53
H_{5-21}	184	111	72	81
	237	101	50	56
	108	83	70	63
H_{0-4}	254	180	52	42
	182	84	65	50
	203	91	64	63
NH	234	112	72	49
	200	102	109	86
	218	109	65	47

K Individual results of mature body weight (90+ days) for all animals used in the physiological sample (gms.)

Rearing Conditions	L-L	B-L	L-D	B-D
	119			
Males	101	100	121	118
	105	106	106	116
	108	101	127	
	106	98	120	
	103	93	128	
	104			
Females	124	138	156	161
	103	130	156	156
	115	154	153	162
	110	106	156	185
	114	109	147	
	133	114		

Handling Conditions	H_{0-4}	H_{5-21}	H_{0-21}	NH
Males	101	106	80	127
	121	111	76	141
	105	115	97	
	96	101	86	
	114	109	98	
			86	
			96	
			88	
Females	129	139	68	126
	105	154	91	126
	103	140	103	164
	143	103	100	151
	125	113	105	160
			107	137
			93	
			98	

L Individual results of brain weights for all animals used in the physiological sample (gms x 10^2)

Rearing Conditions	B-L	L-L	L-D	B-D
Males	82	76	77	68
	72	76	74	71
	76	75	69	
	89	77	61	
	80	75	82	
		76		
		92		
Females	83	78	82	77
	77	81	84	82
	79	78	82	85
	81	81	69	81
	78	67	63	
	88	81		

Handling Conditions	H_{0-21}	H_{5-21}	H_{0-4}	NH
Males	69	81	81	78
	70	79	77	76
	61	76	80	
	64	78	76	
	79	75	81	
	73			
	76			
Females	78	68	72	81
	75	75	72	80
	77	73	75	80
	78	81	82	82
	76	78	78	84
	76			
	75			
	78			

M Individual results of adrenal gland weights for all animals used in the physiological sample (gms. x 10^3)

Rearing Conditions	B-L	L-L	L-D	B-D
Males	19	23	22	25
	25	16	18	19
	23	22	25	
	28	18	16	
	17	20	19	
		19		
		23		
Females	16	15	15	22
	17	16	15	13
	15	10	16	16
	14	14	21	13
	18	20	16	
	15	24		

Handling Conditions	H_{0-21}	H_{5-21}	H_{0-4}	NH
Males	21	17	17	20
	19	25	22	27
	19	21	24	
	19	25	19	
	20	20	19	
	15			
	17			
	16			
Females	9	18	17	15
	12	17	15	16
	12	11	14	14
	14	21	15	14
	12	17	25	18
	14			18
	14			
	14			

N Individual results from plasma cortisol assay for all animals used in the physiological sample (nmols/L)

Rearing Condition	L-L	D-L	L-D	D-D
Males	40.0	23.75	0	0
	57.5	52.25	117.5	7.5
	12.5	15.0	74.05	
	10.0	52.25	5.0	
	2.5	27.5	0	
Females	12.5	0	0	2.5
	10.0	20	6.5	27.5
	62.5	15	0	0
	15.0	7.5	12.5	0
	77.5	0	7.5	
	20.0	0		

Handling Conditions	H_{0-4}	H_{5-21}	H_{0-21}	NH
Males	57.0	122.5	33.25	10.0
	27.5	75.0	23.75	102.6
	90.0	15.0	17.5	
	155.0	17.5	37.5	
	82.0	92.5	87.5	
			52.5	
			35.0	
			104.5	
Females	17.5	0	22.5	72.5
	5.0	22.5	62.5	22.5
	4.75	12.5	30	0
	0	0	0	37.5
	0	0	6.7	
			0	
			0	
			0	