THE PHYSIOLOGY OF MENTAL STRESS : SOME PRACTICAL ASPECTS*

DR. P. K. BRIDGES, T.D., M.D., Ph.D., M.R.C.Psych., D.P.M.

Guy's Hospital Medical School, London

The effects of strong emotion upon physical functions have been recognised for a long time. John Hunter (1728-93), a sufferer from angina, recognised the great power of emotion upon the body when he complained that his life was in the hands of any rascal who chose to annoy him—and that was how it turned out! He was an irascible person, and following an argument, he collapsed and died. Rather more precise consideration of psychosomatic relationships began with William James in 1890. He wrote, 'my theory . . . is that the bodily changes follow directly the perception of the exciting fact, and that our feeling of the same changes as they occur is the emotion'. A similar theory particularly emphasising the role of the vasomotor system came at about the same time from Lange in 1885, hence the James-Lange theory of emotion which has been restated recently by Tyrer (1973).

In 1927 Cannon formulated his views which were more concerned with adrenal medullary activity. He wrote, 'if the secretion of adrenin is increased in strong emotional states and in pain, that constitutes a fact of considerable importance, for, as already mentioned, adrenin is capable of producing many of the bodily changes which are characteristically manifested in emotional and painful experiences' (Cannon 1929). In developing this theory, the now familiar view of emergency preparation for fight or flight was described thus; 'the functions which in quiet times establish and support the bodily reserves are, in times of stress, instantly checked or completely stopped and these reserves are lavishly drawn upon to increase power in the attack and in the defence or flight' (Cannon 1929). In 1932 he introduced the word 'homeostatis' as 'co-ordinated physiological processes which maintain most of the steady states in the organism', previously described by Claude Bernard in 1867 in terms of 'La Fixité du Milieu Intérieur'.

In 1936 Selye first reported the findings which led to his theories about stress and the ideas were developed in his monumental volume entitled 'Stress', published in 1950 and followed by a subsequent 'Annual Report on Stress' which appeared for several years and made much impact on both biology and medicine. Selye proposed what he called a 'General Adaptation Syndrome', described as being in addition to many specific defence reactions, such as maintenance of body temperature, and he said that it was 'an integrated syndrome of closely inter-related adaptive reactions to non-specific stress'.

The word 'stress' has both a popular and scientific use. In the former sense it conveys a disagreeable mental experience, usually involving anxiety, and while this is related to the scientific meaning, the latter has distinct physiological implications. A definition is not easy to devise but, while the popular ideas about stress need not include physiological arousal, the scientific meaning requires

* *Revised version of a Royal Army Medical College Guest Lecture given on 18th May, 1976.*

this. Indeed, Ganong (1975), accepting the prime role of the hypothalamic-pituitary-adrenocortical system like Selye, defined stressors simply as stimuli which increase corticotrophin secretion in normal animals and in man. The definition of stress given by the Journal of the American Medical Association (1954) appears to lean towards the popular and lacks precision: 'Stress implies either an inner conflict or a conflict against circumstances for which no immediate action is appropriate. It implies further that the conflict is protracted, the outcome uncertain, and that the victim is constantly aware of it'.

The concept of stress proposed and the resulting physical responses is obviously a dynamic one and the phrase 'a state of potential energy requirement' conveys the practical element. Stress might also be considered in terms of that which produces disruption of homeostasis or **is felt to threaten to do so**. This is a useful description as it combines both the physical and psychological aspects of stress reactions. Thus, for example, trauma will produce physiological stress responses resulting from bleeding, pain and so on. The threat of trauma will also initiate stress responses if the threat is perceived as such and anxiety results.

Mason (1971) pointed out that the pituitary-hypothalamic-adrenocortical system is highly sensitive to psychological influences. So much is this so that it is very difficult to study the physical aspects of a stressor, confident of eliminating the psychological responses to it. Mason gave an example in which he was studying fasting by simply stopping food to two monkeys in a group of eight housed together. The two monkeys showed significant adrenocortical activation probably because they were ignored when the other monkeys were being fed and also no doubt because they felt hungry. An attempt was made to minimise the psychological variables by placing the fasting monkeys by themselves in a secluded cubicle and they were given pleasantly flavoured but non-nutritive pellets which were similar in appearance and in taste to their normal diet. In these circumstances, stress responses were much reduced although the animals were still not obtaining satisfying food. As another example, exercise by itself is not associated with increased adrenocortical activity unless it is unduly arduous or the attendant conditions are unpleasant, in which circumstances psychological factors will come into play (Davies and Few 1973).

In the final 'Annual Report on Stress' published in 1956, Selye summarised the state of knowledge at that time as follows, 'We still know virtually nothing about the nature of the "first mediator(s)" which transmit the impulse for corticotrophin secretion from the area directly affected by stressors to the hypothalamic-hypophyseal system. Progress has been made mainly in eliminating certain suspected mediators by showing that they could not be the first mediator'. He went on to describe research indicating that adrenaline, noradrenaline, acetylcholine and histamine are not the 'first mediators'. Mason (1971), however, suggests that the primary mediator may be simply the psychological apparatus involved in emotional reactions to threatening or unpleasant factors in the life situation as a whole. This explanation usefully offers a common factor by which a wide variety of stressors, for example, including both heat and cold, pain and starvation, all stimulate responses in a similar way. In this Mason perhaps echoes Sherrington who, in 1948, emphasised the significance of emotion

thus. 'The process by which a reaction of mere "quantum" order is biologically raised to molecular dimensions is called by some biologists "amplification". A means to amplification is emotion. As a physical stimulus a ghost may be a barely threshold power: but given emotion, and it can convulse the whole individual'.

Clearly such a system has considerable biological value. Adaptive stress responses are initiated in advance, when there is only a threat of physical damage, by psychological anticipation which will bring into play emergency systems before possible injury occurs. In addition, arousal will facilitate 'fight or flight', and as a result the danger might be avoided. If injury is caused, pain and fear will enhance stress responses and, up to a point, combat deleterious effects such as shock. It should be remembered that the adrenalectomized animal cannot survive major stress.

Thus, the 'early warning' of potential stress comes first from an appropriate sensory stimulus. But the stimulus requires psychological interpretation, it has to be recognised as being threatening and this process may be faulty. For example, children have to be taught that some sensory stimuli are associated with danger while others are not. They may well lack fear of busy roads but show terror in the presence of a large, harmless dog. The interpretive process varies in that some individuals seem to see threats everywhere while others hardly ever experience fear. The process appears to be abnormal in those with phobias. For reasons that are not precisely known, some individuals habitually regard leaving the house alone or hearing thunder as overwhelmingly threatening. Modification of the perception of danger and also modulation of the resulting psychological experience can be achieved by training individuals to deal with potentially dangerous situations in a controlled way and by developing supportive group attitudes. This is of course well recognised in relation to military training.

We live in what has been called 'The Age of Anxiety'. We are constantly led to fear social failure, we are encouraged to be concerned by accidents in the home, on the roads, danger from cigarettes and even from certain foods. This, together with the considerable, perhaps excessive, security of modern life, makes for over-sensitivity so that even mildly threatening sensory input can produce major responses and it is possible that associated reverberating neuronal activity sometimes occurs which could be the basis of chronic tension, phobic anxiety, obsessional neurosis and some psychosomatic conditions. A person going for an interview, with all its competitive and socially important implications, will psychologically perceive a considerable threat and much physiological activation may result—all to no biological purpose except that cerebral alerting will help if it is not excessive. So perhaps for our anxiety-ridden society, we should add to Cannon's quotation—'fight, flight or fright'. In situations of social anxiety, fight is inappropriate, flight unreasonable so we are left in a state of fright.

There is the possibility that increased physiological activity unnecessarily and too frequently produced might cause functional overload and result in self-damage. Business executives, goaded on by social ambition and their employers' manipulation of their emotional drives, may be in a virtually continuous state of arousal with the possibility of psychosomatic disease resulting from

physiological over-stimulation of vulnerable systems. However, while this is a generally accepted possibility, it is less certain that in states of chronic anxiety there actually is chronic physiological activation although there may well be both individual variability and specific organ vulnerability in some. A recent report on the prevention of coronary heart disease (Joint Working Party 1976) states that while acute stress may precipitate a heart attack, it is difficult to prove that chronic stress contributes to the development of coronary heart disease. Nonetheless, they state that the management of stress is part of good medical practice.

The central modulation of emotions is considered to be associated with the limbic system, previously called the rhinencephalon, first proposed by Papez in 1937, who regarded it as a complex series of integrated relays. Nauta (1971) has stressed the importance of the frontal lobes not only as a 'sensory mechanism', but as an effector organ. He wrote, 'the frontal cortex is in a reciprocal relationship with two great functional areas, namely (1) parietal and temporal regions of the cerebral cortex involved in the processing of visual, auditory and somatic sensory information; and (2) the limbic system and its subcortical correspondents, in particular the hypothalamus. These theories suggest how stress physiology embraces the unitary nature of mind and body, which function together when the organism is threatened. There is then a harmonious interaction as psychological perception leads to arousal, associated with potentially adaptive physical responses.

There is virtually no physiological system unaffected by stress. A wide range of variables have been observed in stress experiments including heart-rate, respiration rate, blood pressure, adrenocortical activity, catecholamine release, gastric motility, finger pulse volume, fore-arm blood flow, plasma free fatty acids, growth hormone and glucagon release, as well as palmar sweating (measured as the psychogalvanic reflex) (Bridges 1974). This has implications of practical importance. For example, what is the relationship of the psychological 'trigger' to the widely ramifying physiological activity and are there differential responses between physiological systems in varying circumstances? It would be difficult to answer such questions in the present state of our knowledge.

There have been a number of studies concerned with responses to psychological stress in man. One of the problems with such investigations is that, as we have seen, it is not easy to devise stresses of significant intensity and without physical components. In an early attempt Levi (1965) reported changes in urinary adrenaline and noradrenaline excretion in subjects watching cinema films of varying content. The experimental subjects were young typists and clearly rather sensitive souls because there were significant increases while watching the film of a 'gruesome ghost story'.

Results were reported for an initial control rest period, then a period while watching the film, followed by a subsequent control rest period. Individual results are not often reported but were given in this paper, from which it was apparent that responsiveness varied a good deal within the group (Figure 1). With as many as half the subjects there was either no increase or an actual fall in catecholamine excretion during the film, the significant mean increase

being contributed to by only about one-quarter, with two who had very high responses. It would have been interesting to know whether these two were different from the rest of the group in any other way. For example, were they unusually mentally vulnerable, had they shown psychiatric symptoms in the past?

Fig. 1. Changes in adrenaline excretion in subjects watching a gruesome cinema film.

In an attempt to determine the influences on physiological responsiveness to stress, medical students taking the Second MB Anatomy oral examination were observed. It was confirmed that this certainly proves to be a considerable stress with, for example, highly significant increases caused in the mean pulse rate from a control value of 72 increasing to 103 per min and in mean blood pressure from 122/79 to 144/92 mm Hg (Bridges, Jones and Leak, 1970). For this series of studies it was postulated that responsiveness might depend on two characteristics—personality and physical constitution. That is, the responses might depend upon an individual predisposition to experience high anxiety either as a psychological function of personality, or else due to an inherent tendency to respond with more or less anxiety as a physiological characteristic.

In this study, personality was measured by means of psychological tests and a rough assessment of constitution was obtained by measuring body-build, which is known to have important constitutional associations. Several related investigations were carried out and it was clear that body-build had a significant

association with the degree of response, while the results from the personality tests did not. The predominantly linear, that is thin, students showed significantly higher adrenocortical responses than did the mainly muscular subjects. Using a wide range of psychological tests, including an analogue scale of subjective anxiety, it became evident that the linear group were in fact experiencing more anxiety, commensurate with their higher plasma cortisol values, compared to the muscular group. Indeed, pooling the results of several investigations there was a significant negative correlation between plasma cortisol stress responses and degree of muscularity, with a significant positive correlation with linearity (Bridges and Jones 1973). The alternative possible explanation that linear subjects show intrinsically enhanced adrenocortical responsiveness to stress was tested by means of tetracosactrin stimulation after dexamethasone suppression and there was no difference at all between the two groups of different body build (Jones and Bridges 1970).

The reports reviewed have practical implications. In both psychology and psychiatry it is very difficult to obtain any kind of objective measure of attributes such as mental stability, drive and motivation. But an increased understanding of stress physiology could be a means of bringing precision into such endeavour. The approach has been used in a number of practical situations. For example, Fishman et al (1962) were concerned with research on groups of volunteers admitted to hospital for experimental purposes. They measured urinary steroid excretion and found that all the groups, except one, followed a similar trend, with high values at first, due to the unfamiliar environment, which fell during the first week. The remaining group showed reverse responses and consisted of impecunious and marginal students who welcomed the period of admission with associated financial relief. The authors conclude that adrenocortical responses are influenced by social factors. Mason (1959) carried out a similar series of studies and found that different groups of experimental subjects had different mean plasma cortisol values, which suggested the possibility of a biological measurement of something as abstract as group morale.

In a study by Blumenfield et al (1970) endocrine observations were carried out on airmen who, during training, needed psychiatric examination, and the results were compared with those obtained from a control group of airmen without evidence of psychiatric problems. Steroid excretion by the former group was significantly higher after dexamethasone suppression and the paper concluded that 'emotional stress can be a cause for the failure of dexamethasone suppression'. In addition failure of suppression has been reported among depressed patients (Carrol, Curtis and Mendels 1976). Such methods could lead to objective means whereby the psychiatrically vulnerable might be detected.

The Vietnam war presented opportunities for studies of those on active service. For example, an absence of enhanced adrenocortical activation was shown in seven helicopter ambulance soldiers while on active missions who had for some time been in combat conditions, which demonstrated that stable individuals can adjust to continuing danger satisfactorily (Bourne, Rose and Mason 1967). The authors' explanation was rather more elaborate; they expressed the view that 'it was apparent that the subjects used extensive and effective psycho-

logical defences to handle the threat of death or mutilation to which they were exposed'. Another study evaluated 12 members of a Special Forces team in an isolated camp, of whom two were officers. It was shown that the two officers had significantly higher mean urinary steroid levels than the nine soldiers. Before, during and after an attack, urine specimens were obtained from one officer and six soldiers. During combat the urinary steroid responses of this officer and also of the radio-operator increased significantly above those of the remaining five men whose values did not rise (Bourne, Rose and Mason, 1968). These findings emphasise in a convincing way the enhanced stress caused by specific social roles and one might not otherwise have been aware of the special pressure on the radio-operator in this group.

Urinary corticosteroid responses were observed in naval aviators during aircraft carrier landing practice and the pilots showed considerable adrenocortical stress responses while their more passive flight officer colleagues did not (Miller et al 1970). This offered an objective indication of the complex and potentially dangerous task of carrier landings which affected the pilot much more than his partner. Again, this is useful confirmation that different levels of arousal occur between personnel in this same situation but with different tasks.

In an investigation by Rubin et al (1969) a group of sailors on an underwater demolition course had serum cortisol estimations carried out three times weekly. They were found to be in a chronic state of stress with values between 550-750 nmol per litre. Against this background of arousal, transient, higher levels were produced by the introduction of new equipment and when beginning new tasks. However, in the case of new tasks, the cortisol values would fall as the technique was mastered and would not rise even if the instructor's demands for that task increased greatly. The highest values of all were found during the affectionately termed 'Hell Week', a period of very intensive activity in the middle of the course. This episode of severe stress might have been used to see whether those with especially high values, or perhaps with levels that did not fall as quickly as others during the subsequent more relaxed week, might have been found among the sailors who did not complete the course. Unusually high values might have indicated unsuitability. The study unfortunately reports only on the 20 who completed the course out of 32 who entered the experiment. These investigations from the American Services show the considerable practical value that is potentially obtainable from such research. Studies such as these have not often been reported from the armed forces of the United Kingdom.

However, there can be methodological problems of many kinds (Bridges 1974). For example, care is needed with the methods used for, and circumstances of, collection of specimens, and with assay techniques. The problem of interpretation of results has also to be considered, of which Figure 2 offers an example. Plasma cortisol and urinary adrenaline and noradrenaline excretion were determined on eight soldiers during a particular stressful activity. The physiological variables were considered separately, but it was found that the percentage adrenaline of total catecholamine excretion correlated significantly with the plasma cortisol values even in this small group. As adrenaline is prefer-

Fig. 2. Plasma cortisol and adrenaline excretion determined during a particular stressful activity.

entially released in stress, its proportion of total catecholamine output would be expected to indicate a stress response. So these two variables appear to be reliably reflecting stress and thus the individual results can be illustrated as shown. It will be seen that four subjects had high values and the results of the other four remained around the normal range so two groups were differentiated. But do those with high values, showing excessive responses, perhaps resulting in impaired performance, indicate that they should be rejected as unsuitable for the activity? Or is it that this stressed group, being clearly aroused, is the more active and the more effective? These questions of course can only be answered by relating other observations to the data and this is where practical assessments of the task and the subjects is necessary in order to place the physiological information into context. Alone, such data can be meaningless but, suitably used, this approach can offer opportunities for the measurement of, for example, psychological vulnerability, adequacy of response to demanding situations and capacity to adapt in adverse circumstances, with considerable precision.

REFERENCES

- BLUMENFIELD, M., ROSE, L. I., RICHMOND, L. H. and BEERING, S. C. (1970). Dexamethasone suppression in basic trainees under stress. *Arch. gen. Psychiat.* **23**, 299

- BRIDGES, P. K. (1974). Recent Physiological Studies of Stress and Anxiety in Man. *Biol. Psychiat.*, **8**, 95
- BRIDGES, P. K., JONES, M. T. and LEAK, D. (1970). A taxonomic study of physiological responses to a psychological stress. *J. Neurol. Neurosurg. Psychiat.*, **33**, 180
- BRIDGES, P. K. and JONES, M. T. (1973). Relationships between some psychological assessments, body-build and physiological stress responses. *J. Neurol. Neurosurg. Psychiat.*, **36**, 839.
- BOURNE, P. G., ROSE, R. M. and MASON, J. W. (1967). Urinary 17-OHCS levels. Data of Seven Helicopter Ambulance Medics in Combat. *Arch. gen. Psychiat.*, **17**, 104.
- BOURNE, P. G., ROSE, R. M. and MASON, J. W. (1968). 17-OHCS levels in combat. Special Forces "A" Team under threat of attack. *Arch. gen. Psychiat.*, **19**, 135
- CANNON, W. B. (1929). *Bodily Changes in Pain, Hunger, Fear and Rage*. Appleton, New York.
- CARROLL, B. J., CURTIS, G. C. and MENDELS, J. (1976). Neuroendocrine regulation in depression. I. Limbic system—adrenocortical dysfunction *Arch. gen. Psychiat.*, **33**, 1039
- DAVIES, C. T. M. and FEW, J. D. (1973). Effects of exercise on adrenocortical function. *J. app. Physiol.*, **35**, 887
- FISHMAN, J. R., HAMBURG, D. A., HANDLON, J. H., MASON, J. W. and SACHAR, E. (1962). Emotional and adrenal cortical responses to a new experience. *Arch. gen. Psychiat.*, **6**, 271.
- GANONG, W. F. (1975). *Review of Medical Physiology*. Lange Medical Publications, California. p. 280.
- JOINT WORKING PARTY OF THE ROYAL COLLEGE OF PHYSICIANS OF LONDON AND THE BRITISH CARDIAC SOCIETY (1976). Prevention of Coronary Heart Disease. *J. roy. Coll. Phycns Lond.*, **10**, 213
- JONES, M. T. and BRIDGES, P. K. (1970). Effects of tetrocosactrin on plasma corticosteroids. in subjects of different body-build. *J. Endrocr.*, **48**, 285
- JOURNAL OF AMERICAN MEDICAL ASSOCIATION (1954). Stress. **155**, 981
- LEVI, L. (1965). The urinary output of adrenaline and noradrenaline during pleasant and unpleasant emotional states. *Psychosom. Med.*, **27**, 80
- MASON, J. W. (1959). Psychological influences on the pituitary-adrenal cortical system. *Recent Progr. Hormone Res.*, **15**, 345
- MASON, J. W. (1971). A re-valuation of the concept of 'non-specificity' in stress theory. *J. psychiat. Res.*, **8**, 323
- MILLER, R. G., RUBIN, R. T., CLARK, B. R., CRAWFORD, W. R. and ARTHUR, R. J. (1970). The stress of aircraft carrier landings. *Psychosom. Med.*, **32**, 581
- NAUTA, W. J. H. (1971). The problem of the frontal lobe: A reinterpretation. *J. psychiat. Res.*, **8**, 167
- PAPEZ, J. W. (1937). A proposed mechanism of emotion. *Archs. Neural Psychiat.*, **38**, 725-743
- RUBIN, R. T., RAHE, R. H., ARTHUR, R. J. and CLARK, B. R. (1969). Adrenal cortical activity changes during underwater demolition team training. *Psychosom. Med.*, **31**, 553
- SELYE, H. (1936). A syndrome produced by diverse nocuous agents. *Nature (London)*, **138**, 32.
- SELYE, H. (1950). *Stress: The Physiology and Pathology of Exposure of Stress*. Acta. Med. Montreal
- SELYE, H. and HEUSER, G. (1956). *Fifth Annual Report on Stress—1955-56*. M.D. Publications, New York.
- SHERRINGTON, C. S. (1948). *The Integrative Action of the Nervous System*. Yale University Press. New Haven, U.S.A.
- TYRER, P. J. (1973). Relevance of Bodily Feelings in Emotion. *Lancet*, *i*, 915.