Physiology and Behaviour of Animal Suffering

Neville G. Gregory
Royal Veterinary College
and
Biotechnology and Biological Sciences Research Council

Blackwell
Science

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Foreword

The human population of the world exceeds six billion and is still growing rapidly. We live in a closed system with finite resources. Whether we like it or not, our interests are frequently in conflict with those of other species. We use animals for food, for companionship, and in research, and we compete with many free-living animals for habitat and food. Side-effects of many of our activities present threats not just to individual animals but to species viability. We cannot avoid having to manage this situation and, frequently and unavoidably, this involves having to weigh the interests of individuals of one species against the interests of individuals of another.

During the last century (and coincident with the period over which much of the human population growth has occurred), remarkable advances in comparative neuroanatomy, physiology and behavioural sciences have provided strong evidence that the capacity for subjective experience of unpleasant (and pleasant) feelings is not limited to humans only. In contrast to the view, commonly-held among influential thinkers prior to this scientific enlightenment, it is now generally accepted that subjective experience, and thus the capacity to suffer, are widespread in the animal kingdom (at least in the vertebrate branch). This knowledge has brought with it a particular responsibility, when pursuing human interests or environmental management for the preservation of biodiversity, to avoid or minimise the risks of causing harm to individuals of other species.

Growing awareness of this responsibility has led, around the world, to a striking proliferation of codes and legislation aimed at protecting and improving animal welfare. In practice, pursuit of these aims depends frequently upon making valid assessments of welfare status. Concern for an animal's welfare is concern about its subjective quality of life – on how it feels. This cannot be measured but can only be inferred from observations of its physical state and behaviour in the light of our own experiences of what it is like to have feelings and of what these are like under various circumstances. Subjectivity cannot be avoided in this process – in the step from what is observed to what is inferred. But, the greater our knowledge of the neurological and other machinery that generates feeling, and of how and when it operates, the safer and surer our inferences are likely to be.

This is a very valuable and timely book in this context. It provides a wide-ranging and informative overview of the physiological and behavioural responses to many diseases, injuries and other stresses, and of the mechanisms that underlie the associated subjective experiences. Improvements in animal welfare do not come about merely by wishing them (to quote Sir Peter Medawar), but depend upon a proper understanding of the causes of suffering and of the ways in which these can be prevented or alleviated. In this book, Neville Gregory makes a major contribution to promoting understanding of animal suffering and thus, both to tackling many forms of it and also to properly taking suffering into account in cost/benefit judgments when pursuit of human or environmental interests put other animals at risk.

James K Kirkwood
June 2004

Preface

Suffering is a state of mind that is difficult to grasp from a conceptual and scientific standpoint. It is not a single entity and it cannot be directly assessed or measured. Instead it is a collective term that indicates unpleasant states of mind.

Suffering can be inferred from observation, enquiry and reasoned analysis. That analysis uses conventional reductionist appraisal of a particular situation. From a knowledge of the accepted causes of suffering, and the responses that usually accompany suffering, we can judge whether or not suffering is likely to be present for that situation.

This book brings together some of the knowledge that should help people arrive at informed judgements using the approach indicated above. It describes the effects and responses during various deprivations and insults in animals, along with the perceptions that occur in some comparable situations in humans. The scientific knowledge is, however, incomplete, and so our judgements will be limited by some uncertainties.

We are not always in a good position to appreciate what goes on in an animal's mind, and so our judgements on suffering will also lack rigorous proof. Dismissing the presence or existence of suffering on the grounds of absence of proof is sometimes used as an obtuse way of dismissing a concern about suffering. However, absence of proof is not proof of absence. Instead, logical constructs that argue for the presence of suffering in a particular situation, call for equally logical constructs if those concerns are to be dismissed or discounted.

This book does not provide the reader with moral judgements or views. The aim is to help the reader in his or her thinking, rather than telling him or her what to think. It intentionally avoids giving opinions about the acceptability of causes of animal suffering. Instead it provides a technical base that can be incorporated into ethical thinking.

Nevertheless, some of the descriptions of the work on injuries and insults that went towards compiling this book were harrowing to read, and in the author's view it would be unacceptable ever to repeat some of those experiments. A few of those descriptions have been included along with the pathophysiology because they

are helpful to understanding suffering, and should help in treating similar cases that may occur in practice in the future.

The ideas on how this book should be written were developed from discussions with Professor David Mellor of Massey University, and I am grateful to David for his constructive thoughts.

N.G. Gregory

Introduction

1

1.1 What Is Suffering?

Suffering is an unpleasant state of mind that disrupts the quality of life. It is the mental state associated with unpleasant experiences such as pain, malaise, distress, injury and emotional numbness (e.g. extreme boredom). It can develop from a wide range of causes. For example, it occurs when there is misery during exposure to cold, with the sense of fatigue and depression during cancer and when there is unremitting pain from chronic headache. Some of the general mental states that contribute to suffering in humans are given in Table 1.1.

1.2 Why Worry about Animal Suffering?

The main reason for being concerned about human and animal suffering is a sense of respect and fairness towards others. Many people feel that needless suffering is unfair, and should be controlled or avoided. Society should not be responsible for needlessly ruining other peoples' or animals' lives. This is a moral outlook, and it inevitably varies between individuals. Some people care. Others do not.

1.3 When Can We Stop Worrying about Animal Suffering?

One of the dilemmas of worrying about suffering is in knowing when to stop being concerned. Do you stop worrying at a human, a mouse or an earthworm? Buddhists strive to minimise all death and suffering, and in some sects it is inappropriate to kill even an earthworm, because it might be a reincarnation of a human. Others take the view that there is no need to be concerned about suffering

Table 1.1 Examples of emotional and mental states that can lead to suffering when they become severe or protracted.

Negative emotional and mental states		
fear	anxiety	sadness
irritation	phobia	bitterness
starvation	boredom	anguish
sickness	depression	mental illness
frustration	pain	paranoia
fatigue	distress	despair
thirst	nausea	torment
	loneliness	longing

in 'lower' life forms because they do not have the capacity to suffer (Rose, 2002). Where can we draw the line and say that suffering no longer exists?

The forms of suffering listed in the third column in Table 1.1 have a higher degree of complexity than those on the left. Intuitively, one might expect the features on the right to be unique to humans or a limited number of mammals, whilst those on the left occur in a larger number of species. This seemingly obvious statement introduces the first dilemma: when trying to decide whether a particular species has the **capacity to suffer**, one has to make clear which form of suffering is being considered.

One approach which might pre-empt that complication, and help simplify decision making, is to consider which species seem to be able to think for themselves. Ability to learn might be considered a sign that a species has some **cognitive capacity**, and cognition is presumably a prerequisite for suffering. Scientifically, a more convenient starting point would be to assume the inverse. Let us take the position that animals that show limited **ability to learn** probably have limited cognitive capacity. We may be concerned with conserving them as individuals and as a species, but we are let off the hook from worrying about whether they can suffer.

Agar (1925) approached this question by testing whether water fleas (*Daphnia carinata*), water mites (Hydrachnidae) and freshwater crayfish (*Parachaeraps bicarinatus*) could learn to avoid an aversive stimulus (Figures 1.1 & 1.2). Each type of animal was placed in the centre leg of a Y-maze and subjected to an unpleasant stimulus, which was either CO_2 in the water or decreasing water depth, to encourage them to swim into one of the side limbs. In one of the side limbs they always experienced an electric shock and in the other there was no shock. By repeating this test many times, their ability to learn, remember and execute a correct decision was evaluated. The *Daphnia* and Hydrachnids failed to learn and adapt, even though they showed a violent reaction to the electric shock. The young crayfish, on the other hand, quickly mastered the situation and avoided the wrong limb. It was more proficient at learning and remembering.

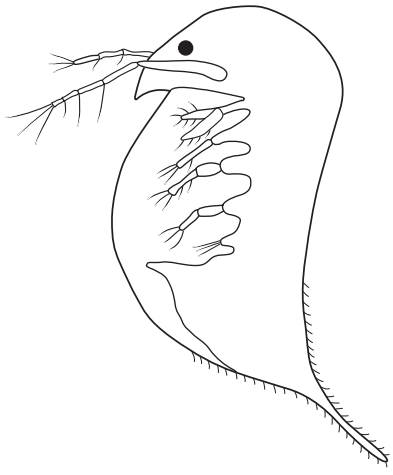

Figure 1.1 Water flea *(Daphnia)*.

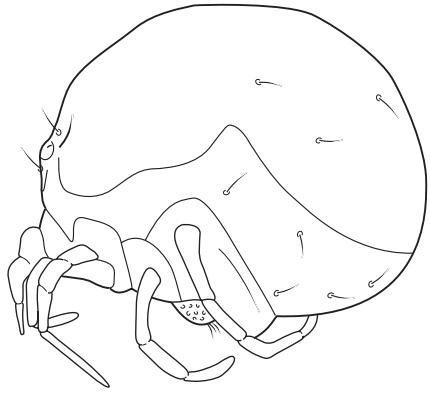

Figure 1.2 *Hydrachna* sp. (Hydrachnidae).

Crayfish also seem to be clever at learning whether a threatening stimulus is a real threat. When a wild-caught crayfish is first handled it is defensive and, if it has cognitive capacity, the impression is that it is apprehensive. It raises its claws in a defensive manner when approached. It wheels round to keep facing the approaching hand and, when seized, it fights to escape. We could interpret this as apprehension and fear. After some days, these fear reactions completely disappear. The animal ceases to threaten the approaching hand with its claws, and remains quiet when picked up. One interpretation is that it learns that the experience was not so bad, or, maybe it adopts a form of learned helplessness. Alternatively, was it a form of subconscious adaptation?

Another tantalising but perplexing finding is the impact of stress on the single-cell organism *Euglena*. They show a more rapid flight response away from a bright light if they have previously been exposed to a pressure shock wave (Murray, 1971). The pressure-shocked *Euglena* were sensitised to the next unpleasant stimulus, which happened to be the light. If this sensitisation to stress was subconscious, then can stress-induced sensitisation be subconscious in other members of the animal kingdom? If so, what are those behavioural situations?

The conclusion from many other studies on protozoa and on coelenterates is that it is not clear whether or not members of these phyla can learn (Jensen, 1964). They can show learning-like behaviour, but the problem is in distinguishing between learning, acclimatisation, habituation, facilitation and adaptive responses. The importance of these distinctions becomes clearer by considering the following example of an acquired response in the sensitive plant (*Mimosa pudica*), which has no cognitive capacity.

Each leaf of this plant is divided into 10 to 20 leaflets, which fold together in pairs when the plant is touched or mechanically shaken. The folding reaction following shaking is immediate. The plant also folds its leaflets at night, but this is a much slower response. A key feature is that the rapid folding response can be conditioned, using darkness as a conditioned stimulus before shaking which is the unconditioned stimulus. The plant folded its leaflets more rapidly to darkness once it had been trained to 'expect' a vigorous shaking as soon as the lights went out. This finding gives the impression that this plant can anticipate a good shaking, but because this occurred in a plant we cannot conclude that it was a cognitive 'anticipatory response'. Instead, it must have been a functional adjustment (Armus, 1970). The same applies to many studies which have examined simple life forms in the animal kingdom. For the purposes of understanding the ability to suffer, we need to distinguish between true cognitive learning and non-cognitive adaptation.

Some simple animals show very interesting learning or adaptive capacities. The earthworm *Lumbricus terrestris*, for example, can learn to distinguish between the limbs of a T-maze to gain access to moist earth or moss, rather than a sandpaper floor and an electric shock. Earthworms were slower at acquiring this skill in the morning compared with the evening (Arbit, 1957). An even more 'primitive' life-form, the planarian worm *Cura foremanii*, 'learnt' to move faster to intercept a photodiode beam in order to extinguish a bright light for 15 minutes (Best, 1964). This was an operant conditioning response, which in other species would usually be assumed to be a form of intelligence. But was it a subconscious response?

There is no doubt that habituation and some forms of learning in animals can be subconscious. Locusts, grasshoppers and wetas can be trained to switch off a noise source set at an irritating vibration frequency. Perhaps this was subconscious learning, as decapitated locusts and grasshoppers also learnt to turn off the sound. Decapitated wetas were not so adept, but this was because head removal was too traumatic for this particular insect.

Subconscious learning also seems to exist in the mammalian foetus. The level of oxygenation *in utero* is thought to be insufficient to support conscious activity in the foetal lamb brain (Mellor & Gregory, 2003). However, a number of studies have shown that the foetus is capable of learning. For example, in experiments by Hepper (1991), the rat foetus was found to be capable of associative learning, and recall of that learning persisted into infancy. Other studies have shown that aversive conditioning can be induced in the rat foetus.

Both conscious and subconscious learning have a molecular basis. In the case of long-term potentiation (LTP), which is a form of associative learning, there are chemical changes which involve activation of *N*-methyl-D-aspartate (NMDA) receptors (Skuse, 2000). These receptors control calcium entry into neurones, which in turn sets off a chemical cascade that ends with the phosphorylation of a protein called cyclic AMP-responsive element-binding protein (CREB). CREB is a transcription factor which regulates genes that enable the maintenance of LTP at the cellular level. In mice, CREB is involved in fear conditioning, spatial learning and social learning. It also serves a function in invertebrates. For example, it is important in forming long-term memory in the fruit fly (*Drosophila melanogaster*) and soil nematode *Caenorhabditis elegans* (Figure 1.3). It is quite plausible that proteins such as CREB form a common link between conscious and subconscious memory processes.

None of these findings tells us when to stop worrying, but they do tease our curiosity and they help us form impressions. Let's take a different approach. Can we stop worrying about suffering in a species if it is unable to experience **pain**? This begs the question, which life-forms can experience and suffer pain? An animal can feel pain at a conscious level if it meets the following criteria:

- it possesses receptors sensitive to noxious stimuli;
- its brain has structures analogous to the human cerebral cortex;
- nervous pathways link the receptors to the higher brain;
- painkillers modify the response to noxious stimuli;
- the animal responds to noxious stimuli by consistently avoiding them;
- the animal can learn to associate neutral events with noxious stimuli;
- it chooses a pain killer when given access to one, when pain is otherwise unavoidable.

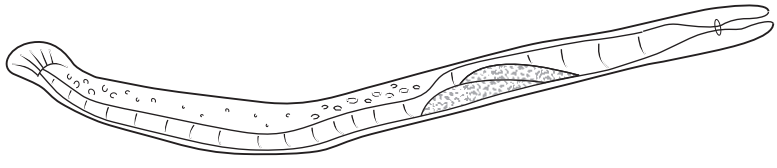

Figure 1.3 Soil nematode *(Caenorhabditis elegans).*

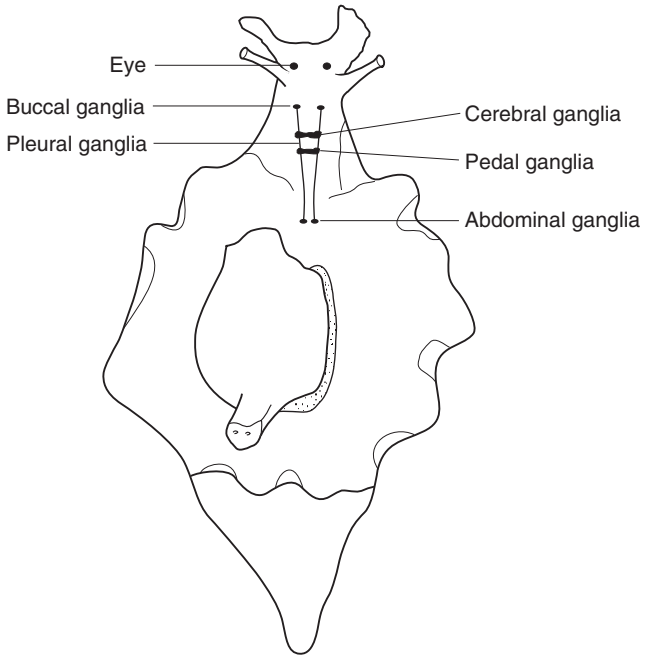

Figure 1.4 Sea hare *(Aplysia californica).*

There are few species which have been evaluated for all these criteria, and so, for the time being, we have to accept an incomplete picture and form impressions instead of making conclusions.

One school of thought considers that some invertebrates are able to experience pain. This is supported by particularly convincing work done by Kavaliers *et al.* (1983) in the land snail. When placed on a hot plate at 40°C, the snail lifted the anterior portion of its foot. Morphine increased the time taken to respond, whereas naloxone reduced it, and abolished the effect of morphine. In other species, the mollusc *Aplysia californica* withdraws its tail when the skin is pinched (Figure 1.4). This animal can express sensitisation which is equivalent to hyperalgesia, and it is being used as a model for neuropathic pain (Woolf & Walters, 1991). The nematode *Caenorhabditis elegans* has a primitive nervous system with only 302 neurones, one of which is the so-called ASH neurone which is functionally analogous to vertebrate mechano-nociceptive neurones that mediate pain (Kaplan & Horvitz, 1993). This species is used in experimental models of hyperalgesia (Wittenburg & Baumeister, 1999). Lastly, the leech *Hirudo medicinalis* has polymodal neurones which respond to temperatures over 38°C, and to noxious chemicals such as acetic acid and capsaicin (Figure 1.5). Together, these findings help to focus our question, but more studies along the lines of Kavaliers *et al.* (1983) are needed in other

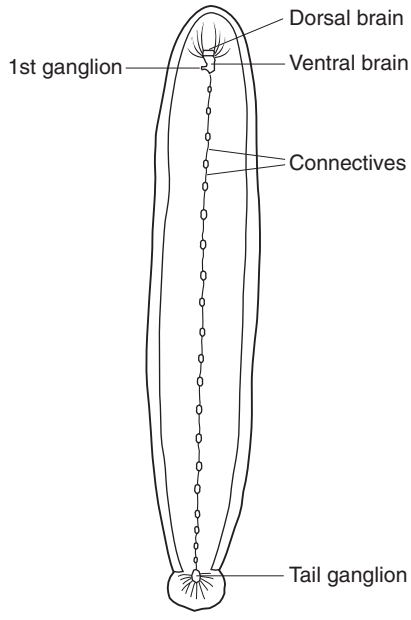

Figure 1.5 Leech *(Hirudo medicinalis)*.

invertebrates before we know where in the evolutionary tree the capacity for pain emerged.

People will inevitably vary in their judgement as to when suffering should be managed. In addition, decisions will depend on the feasibility of treating or preventing the suffering, the alternatives that may be available and whether they also present hazards of suffering, the cost of controlling the suffering and whether the individual actually cares. Not everyone wants to get involved with situations where there is animal suffering. However, society in general can have responsibilities to guard against suffering, even though it may be a select group of people who are the guardians. That responsibility applies particularly to animals that depend on or are strongly influenced by human activities.

1.4 Recognising Suffering in Animals

Many scientific disciplines use experimental **animals as models** for human disease or dysfunction. This book takes the opposite approach. It takes the human as a model for animals in understanding pain, unpleasant sensations and suffering. This is a logical approach because experience in humans is the only context in which we learn what pain and suffering are like. The weaknesses in doing this are much the same as using animals as models for the human. We do not always know how

relevant the model is to the target species. This does not mean that the model can be dismissed because of uncertainty. Instead, it means that the human model should be used wisely, in a considered way, and its main value is in highlighting potential forms of suffering.

Recognising suffering is of obvious importance if we really care about animal suffering. How do we recognise when an animal has a specific type of suffering, such as a headache? Presumably it would look ill or depressed, but we have no way of knowing whether this is due to a general sense of sickness, a headache or simply a bad mood. One approach to understanding the signs associated with specific forms of suffering is to see what they are like when induced pharmacologically. This has been done in studying the signs associated with **nausea**.

Apomorphine causes nausea and vomiting in humans, and it is an emetic in a wide range of species. Normally, birds do not vomit. They can regurgitate crop contents when feeding young, but it would be unusual for a bird to bring up the contents of its proventriculus. In the pigeon, instead of inducing emesis, apomorphine causes the bird to peck rapidly at the floor and other objects, without eating anything. This behaviour comes on very rapidly and is so compulsive that in some cases the beak has been injured. After this pecking phase the bird is subdued and seemingly depressed. It is thought that the pecking phase is analogous to the chewing phase that is seen in other species before they vomit.

Learning from practical experience is another way of recognising the signs of sickness and understanding what the animal might be feeling. Veterinary practitioners are in a particularly strong position to do this because their job brings them into contact with animal suffering every day. The detailed descriptions they provide can be very helpful. Take the following account of the signs associated with **sinusitis** that occurred when dirty dehorning equipment had been used in a herd of cattle:

- the animals rested their muzzles on a stationary object, such as a water trough;
- they head pressed or extended their head and neck with their nose held parallel to the ground and their eyes partially or fully closed;
- palpation over the sinus elicited signs of pain in some animals.

Anecdotes such as this form the basis for diagnosis and understanding the behaviours associated with particular types of suffering.

1.5 Can Animals Go Mad?

In the past, psychological research into **neuroses** using animals was scorned by psychiatrists because it was assumed that insanity only occurs in humans. It was thought that animals cannot go mad, even though the signs of rabies in dogs were fully appreciated. In 1921, a significant experiment was conducted on a dog, which

helped to change that outlook (Abramson & Seligman, 1977). This dog was a good-natured animal and easy to handle. It was trained to be led to a room where it received its food. In that room a circle of light was shone onto a screen in front of the dog, and this was followed by food. Once the dog had developed a salivation response when the light was turned on, the shape of the projected light was altered the following day. If the light was elliptical instead of a circle, there was no food, but when it was a circle, the dog was always given its food. The dog learnt over a period of days to anticipate food on this basis. However, its discrimination broke down as the ellipse got closer in shape to a circle. At a 9:8 ratio of the axes, the dog became confused, and there was a dramatic change in its behaviour. The once-quiet dog became highly aroused. It began to squeal and tried to destroy the experimental equipment. It refused to enter the feeding room, and barked violently when feeding time approached. This dog did not go mad, but it developed neurotic responses out of frustration. Since that experiment there have been many other experimental and clinical reports on neurotic behaviour in domesticated animals, and the general view is that some animals can and do become neurotic, which in extreme cases is the equivalent of madness.

Some animals seem to be able to **hallucinate**. This has been observed in cats, and the behaviours were similar to those seen in other cats given the psychogenic drug LSD, and included:

- staring;
- limb flicking;
- abortive grooming;
- looking around the floor, ceiling or walls, tracking invisible objects with their eyes and sometimes hissing, batting or pouncing at them.

1.6 What Constitutes Animal Suffering?

One of the shortcomings in using the human as a model for studying animal suffering is that humans do not share all the same senses as animals. These deficiencies limit the inferences we can make from self-experimentation and observation. We do not have:

- an electrosensory lateral line;
- a vomeronasal organ;
- ability to detect infrared radiation;
- magnetoreceptors;
- specific pheromones.

In addition, the frequency range of our hearing is limited in comparison with insects and some other animals. Our proficiency at chemoreception is inferior to

that of many aquatic animals. We do not know what life is like for cavefish (*Astyanax hubbsi*) or mole rats (*Spalex ehrenbergi*) which are naturally blind, or for whales which have limited ability to smell, taste, feel with their skin and see. Other senses are more important to these animals, and the implications are difficult to appreciate fully.

One of the most exciting advances in neuroscience is **neuroimaging**. This technique is allowing us to recognise which cortical regions of the human brain are activated when we have particular feelings. We are now beginning to understand where in the cortex the different forms of suffering are integrated. For example, we now recognise that thirst perception involves the posterior cingulate cortex, and that several forms of pain are registered in the anterior cingulate cortex and insula. When the cortical sites associated with suffering have been fully mapped, we may be in a position to identify the corresponding cortical and telencephalon sites in animals. This in turn could lead to the experimental diagnosis of suffering based on the activation or inhibition of particular brain regions.

1.7 Conclusions

The main points made in this chapter are as follows:

- Deciding when to care about suffering has moral as well as practical considerations. Morals may be influenced by personal outlook, but society in general has a responsibility to care about animal suffering.
- The forms of suffering that can be experienced by 'lower' life forms are narrower than those experienced by 'higher' life forms, and so it is helpful to specify the form of suffering when discussing capacity for suffering.
- Cognition is a prerequisite for mental suffering. In some cases, inability to learn can be an indication of limited cognitive capacity. However, learning can be a subconscious activity and so, in 'lower' life forms, an ability to learn does not necessarily demonstrate cognitive capacity or capacity to suffer.
- Pain is an important perception that can lead to suffering. Scientifically, there are seven criteria that have to be met before there is adequate proof that a species can experience pain. On its own, one of the most convincing criteria is the self-selection of a pain killer during chronic or otherwise unavoidable pain. Few species have been tested in this paradigm.
- Experience in the human provides a useful model for recognising insults and situations where suffering could occur in 'higher' animals.
- Some pharmaceuticals can provoke specific types of discomfort or distress. In the future they may be helpful in allowing us to recognise the behavioural signs associated with specific types of suffering in 'higher' animals.
- 'Higher' animals can display neurotic behaviour patterns which are analogous to some forms of mental disorder in humans.

- Some species have sensory modalities which humans do not possess. This makes it difficult for us to appreciate the importance of loss of those sensory modalities in terms of potential suffering.
- In the future, we may get greater insight into different species' repertoire for suffering through comparative neuroimaging of cortical homologues in the brain.

Stress

2

Stress is a physiological disturbance that is imposed by a stressor, such as a threatening or harmful situation. It is associated with suffering when there is mental distress. It occurs following physical trauma, during disease and in emotional conflicts. When the stress is severe, homeostatic processes are put under abnormal pressure, behaviour becomes disorganised and there can be pathological effects. Stress is usually classified according to the stressor, which can be either the stimulus that provokes the stress response or the context in which the stress occurs. The physiological responses are not necessarily the same for all stressors, but some common features are highlighted in this chapter.

2.1 Stress Physiology

The **physiological stress pathways** in the brain are channelled along two main routes:

(1) corticotrophin releasing hormone activation of the hypothalamic–pituitary–adrenal (HPA) axis;
(2) activation of the sympathetic nervous system (SNS).

Corticotrophin releasing hormone (CRH) is synthesised at a number of sites in the brain including the hypothalamus, amygdala, *stria terminalis*, prefrontal cortex and cells surrounding the *locus coeruleus* (LC) (Figures 2.1 & 2.2). CRH from the hypothalamus stimulates the secretion of adrenocorticotrophic hormone (ACTH) from the anterior pituitary, which in turn stimulates the secretion of glucocorticoids from the adrenal cortex.

When CRH is administered centrally into the brain of a laboratory animal, it has anxiogenic effects and can enhance behavioural signs of **fear**, panic or depression. These and the other main roles of CRH are listed below. Some of these effects are mediated by the amygdala, and the prefrontal and cingulate cortical areas in

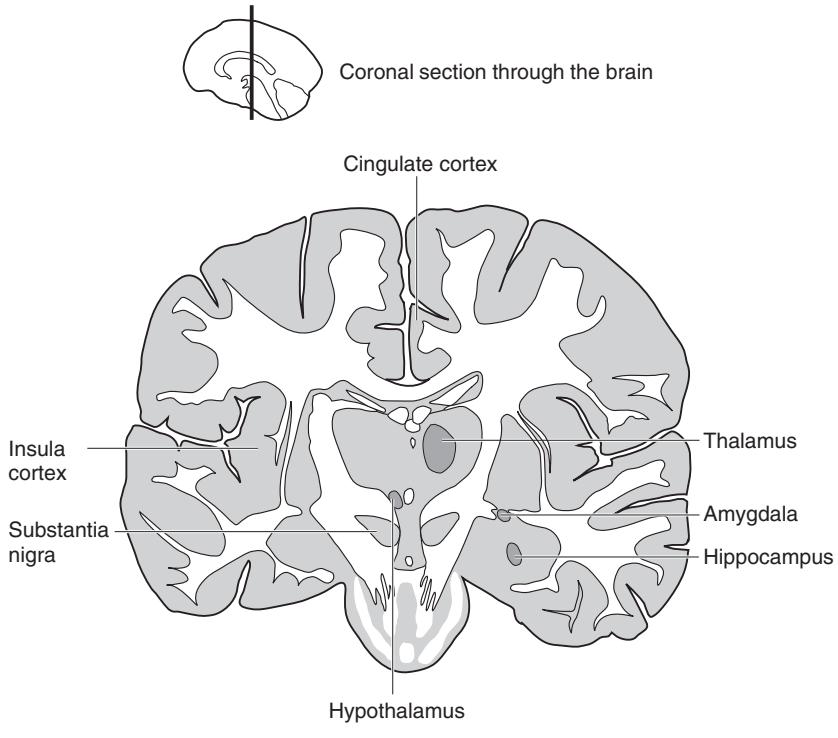

Figure 2.1 Coronal section through the human brain.

the brain (Steckler & Holsboer, 1999), and in humans, an overactive CRH pathway has been implicated in stress-related anxiety, depression disorders, and anhedonia. Central administration of ACTH can also produce some anxiety-like behaviours in rats. These include excessive grooming, increased submissive behaviour, and protracted avoidance responses (see below).

Stress effects that are produced by central administration of CRH in the rat are:

- increase in heart rate and blood pressure;
- defecation;
- suppression of exploratory behaviour;
- induction of grooming behaviour;
- increased activity;
- reduced feeding;
- disruption of reproductive behaviour;
- exaggerated acoustic startle response;

continued

- enhanced fright-induced freezing and fighting behaviour;
- enhanced fear conditioning.

The functions of CRH are:

- activation of the HPA axis through the release of ACTH from the pituitary;
- stimulation of the release of β-endorphin from the pituitary;
- enhancing central activation of the autonomic nervous system;
- stimulation of noradrenaline release centrally;
- activation of the gastrointestinal system;
- mediation of aversive behavioural responses;
- production of anxiogenic-like effects.

One of the main **roles of the HPA** axis is in combating disease. Cytokines produced in response to disease organisms stimulate ACTH release from the pituitary, partly through activating CRH release. ACTH passes to the adrenal cortex by the bloodstream where it stimulates the release of glucocorticoids. The glucocorticoids check the development of inflammation, preventing it from getting out of control, and promote the supply of substrates required during repair and recovery. They

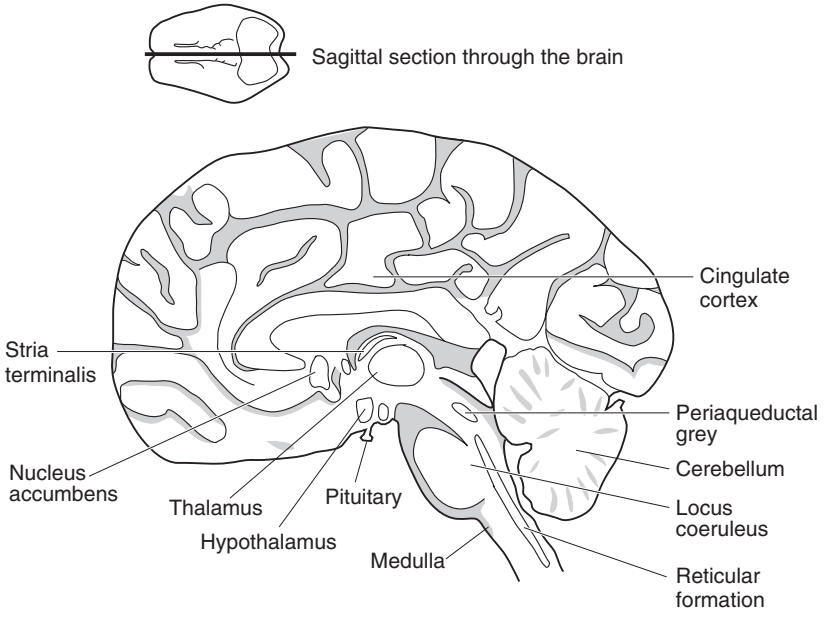

Figure 2.2 Sagittal section through the human brain.