

the retro-fitting of precipitators on uncontrolled incinerators, or perhaps the installation of electrostatic precipitators on uncontrolled incinerators, or perhaps the retro-fitting of precipitators on units equipped with low pressure/efficiency scrubbers.

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## Minireview

### Do insects feel pain? – A biological view

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The question of whether insects, or indeed other invertebrates, have a pain sense has received little attention in the literature, despite its obvious biological interest and the ethical implications of the human treatment of insects and other invertebrates. The relevance of this question is that, whilst we could scarcely conceive of a world in which pest insects are not regularly damaged and killed in vast numbers by human design and many others killed incidentally in our daily activities, the experimental biologist still has to face decisions on how to handle his insect material. Pain, as understood in humans, is a variable, subjective experience involving a class of sensations with which is associated a characteristic 'negative affect and aversive drive'<sup>15</sup>. Its quality and severity may be strongly modified by factors including previous experience, non-nociceptive sensory information, focusing of attention by the subject, and the perceived significance of the experience<sup>15,16</sup>. The unpleasant emotional qualities and strong motivation to remove the source of stimulation appear largely to comprise the experience known generally as 'suffering'. The occurrence of 'suffering' in other animals is usually inferred from physiological and behavioral changes such as flexor reflexes, blood pressure increases, tachypnoea and vocalisation<sup>25</sup>, all of which are normally concomitants of severe pain experiences in humans. This inference becomes progressively less defensible as animals phylogenetically more remote

from man are considered. The standard reference work on the structure and function of the nervous systems of invertebrates<sup>3</sup> suggests only that pain is inferred if an animal shows behavioral reactions resembling those of a human in pain, the decreasing similarity of reaction in simpler animals being taken to indicate a gradual evolution of a pain sense with the appearance of increasingly complex animals.

Although there is no conclusive proof as to whether an insect can experience something akin to human pain, logical analysis of known examples of insect behavior and physiology may facilitate a rational decision. In the only published examination of the possibility of insect pain known to us, Wigglesworth<sup>24</sup> has, by inference from his observations of insect behavior, concluded that while most of the manipulations to which insects are commonly subjected probably do not cause them pain, certain stimuli, such as high temperature and electric shocks, apparently do so. We here examine the question from three aspects: firstly, the adaptive role of pain in mammals and the relevance of this to insect biology; secondly, the neural basis of nociception and pain perception in mammals and its relation to the insect nervous system; and thirdly, the similarities and contrasts between the behavior of insects and mammals undergoing trauma or noxious stimulation.

Pain may induce a suffering mammal to withdraw from or otherwise neutralize the causative agent and