

Fundamental feelings

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The groundwork for the science of emotion was laid down most auspiciously over a century ago, but neuroscience has given the problem a resolute cold shoulder until recently. By the time that Charles Darwin had remarked on the continuity of emotional phenomena from non-human species to humans; William James had proposed an insightful mechanism for its production; Sigmund Freud had noted the central role of emotions in psychopathological states; and Charles Sherrington had begun the physiological investigation of the neural circuits involved in emotion, one might have expected neuroscience to be poised for an all-out attack on the problem. It is not usually appreciated that the probable cause of the neglect of the topic was the improper distinction between the concepts of emotion and feelings.

Some traits of feelings — their subjective nature, the fact that they are private, hidden from view, and often difficult to analyse — were projected onto emotions, so that they too were deemed subjective, private, hidden and elusive. Not surprisingly, neuroscientists were disinclined to give their best efforts to a problem that did not seem to be amenable to proper hypothesizing and measurement. Somewhat alarmingly, this conflation of the two concepts persists, as does the idea that the neurobiology of feelings is out of reach. A clarification is in order.

An emotion, be it happiness or sadness, embarrassment or pride, is a patterned collection of chemical and neural responses that is produced by the brain when it detects the presence of an emotionally competent

stimulus — an object or situation, for example. The processing of the stimulus may be conscious but it need not be, as the responses are engendered automatically. Emotional responses are a mode of reaction of brains that are prepared by evolution to respond to certain classes of objects and events with certain repertoires of action. Eventually, the brain associates other objects and events that occur in individual experience with those that are innately set to cause emotions, so that another set of emotionally competent stimuli arises.

The main target of the emotional responses is the body — the internal milieu, the viscera and the musculoskeletal system — but there are also targets within the brain itself, for example, monoaminergic nuclei in the brainstem tegmentum. The result of the body-targeting responses is the creation of an emotional state — involving adjustments in homeostatic balance — as well as the enactment of specific behaviours, such as freezing or fight-or-flight, and the production of particular facial expressions. The result of the brain-targeting responses is an alteration in the mode of brain operation during the emotional body adjustments, the consequence of which is, for example, a change in the attention accorded to stimuli.

Emotions allow organisms to cope successfully with objects and situations that are potentially dangerous or advantageous. They are just the most visible part of a huge edifice of undeliberated biological regulation that includes the homeostatic reactions that maintain metabolism; pain signalling; and drives such as hunger and thirst. Most emotional responses are directly observable either with the naked eye or with scientific probes such as psychophysiological and neurophysiological measurements and endocrine assays. Thus, emotions are not subjective, private, elusive or undefinable. Their neurobiology can be investigated objectively, not just in humans but in laboratory species, from *Drosophila* and *Aplysia* to rodents and non-human primates.

A working definition of feelings is a different matter. Feelings are the mental representation of the physiological changes that characterize emotions. Unlike emotions, which are scientifically public, feelings are indeed private, although no more subjective than any other aspect of the mind, for example my planning of this sentence, or the mental solving of a mathematical problem. Feelings are as amenable to scientific analysis as any other cognitive phenomenon, provided that appropriate methods are used. Moreover, because feelings are the direct consequences of emotions, the elucidation of emotional neurobiology opens the way to

Emotion

Emotion and feelings are closely related but separable phenomena; their elucidation, at long last, is now proceeding in earnest.

elucidating the neurobiology of feelings.

If emotions provide an immediate response to certain challenges and opportunities faced by an organism, the feeling of those emotions provides it with a mental alert. Feelings amplify the impact of a given situation, enhance learning, and increase the probability that comparable situations can be anticipated.

The neural systems that are involved in the production of emotions are being identified through studies of humans and other animals. Various structures, such as the amygdala and the ventromedial prefrontal cortices, trigger emotions by functioning as interfaces between the processing of emotionally competent stimuli and the execution of emotions. But the real executors of emotions are structures in the hypothalamus, in the basal forebrain (for example, the nucleus accumbens) and in the brainstem (for example, the nuclei in the periaqueductal grey). These are the structures that directly signal, chemically and neurally, to the body and brain targets at which alterations constitute an emotional state.

No less importantly, recent functional imaging studies reveal that body-sensing areas, such as the cortices in the insula, the second somatosensory region (S2) and the cingulate region of the brain, show a statistically significant pattern of activation or deactivation when normal individuals experience the emotions of sadness, happiness, fear and anger. Moreover, these patterns vary between different emotions. Those body-related patterns are tangible neural correlates of feelings, meaning that we know where to look further to unravel the remaining neurophysiological mysteries behind one of the most critical aspects of human experience. ■

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FURTHER READING

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