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Emotions and Feelings

A Neurobiological Perspective

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ABSTRACT

After receiving remarkable attention from scientists during the nineteenth century, emotion was relatively neglected throughout the 20th century, especially within the field of neuroscience. Recently, however, neuroscientists have begun again to advance the understanding of the neural mechanisms behind emotion.

Emotion is as much amenable to scientific study as any other aspect of behavior. Moreover, emotion is not a luxury: it is an expression of basic mechanisms of life regulation developed in evolution, and is indispensable for survival. It plays a critical role in virtually all aspects of learning, reasoning, and creativity. Somewhat surprisingly, it may play a role in the construction of consciousness.

In this chapter I review a theoretical framework which places emotion and the phenomenon that follows emotion, feeling, in an evolutionary perspective and discuss their biological roles in homeostasis. I shall also review some current evidence on neural systems involved in emotion and feeling based on the lesion method and functional neuroimaging studies.

What are emotions and feelings from the neurobiology perspective? How do organisms produce these phenomena and, in particular, how does the brain implement them? What are emotions and feelings for? Recent advances in biology, cognitive science, and neuroscience are beginning to help us answer these questions – not completely, by any means, but in ways that suggest progress is being made. In this chapter I give a sketch of some possible answers.

Let me begin with the matter of what emotions and feelings are. The statement of the problem suggests that a research distinction can be drawn with advantage between the two, that emotions and feelings are not the same thing as objects of study, notwithstanding the fact that, in real time and real life, emotion and feeling seemingly occur as if they were merely two sides of the same coin, affect pure and simple. Many are skeptical about the need for such a distinction. Some argue that the current usage of these terms has made them synonymous and that it is difficult if not impossible

https://doi.org/10.1017/CBO9780511806582.004 Published online by Cambridge University Press

to expunge the conflation. Others contend that the term "emotion" is perfectly adequate to describe both emotions and feelings. Still others will say that "feeling" is a hopeless concept: too vague, too slippery, too bad. By now, however, we know enough about the nature of affective processes to state that there are distinctive, albeit interrelated, physiological and mental events that benefit from separate designations. We also know that different names allow for a clearer communication regarding the profile of these events and the related theories and hypotheses. The fact that the words chosen to designate the two sets of phenomena are, respectively, emotion and feeling, is neither divinely ordained nor arbitrary. The two words effectively interconnect a historical tradition with our current understanding of the phenomena they are supposed to denote. They are rather good words for the purpose.

WHAT EMOTIONS AND FEELINGS ARE

The following are definitions of these phenomena, as I see them today. Note that these definitions are provisional, that they are neither the definitions of the problems with which I remember starting my work on this subject nor the definitions we are likely to come to, in the years ahead, as new findings change the ways in which we conceive these problems and carve out revised descriptions. Working hypotheses in the form of definitions is perhaps the best way to designate the statements that follow.

In the simplest and most general wording possible, emotions are *bioregulatory reactions* that aim at promoting, directly or indirectly, the sort of physiological states that secure not just survival but survival regulated into the range that we, conscious and thinking creatures, identify with *well-being*.

What are these reactions made of? They are constituted by a *patterned collection of chemical and neural responses* that the brain produces when it detects the presence of an *emotionally competent stimulus*. The processing of the stimulus may be conscious or nonconscious, but in either case the responses are produced automatically.

And what is an emotionally competent stimulus? It is an object or a situation actually perceived or recalled from memory. Some stimuli achieve competent status in the course of evolution. As a result of the brain's design, stimuli that belong to certain classes of objects and events predictably cause the repertoires of action, internal and external, which we call emotions. Eventually, the brain associates other objects and events that occur in individual experience with those which are innately set to cause emotions, and as a consequence an additional set of emotionally competent stimuli arises. By the ripe age at which one gets invited to write scientific essays, most if not all objects and situations in the world evoke *some* emotion, strong or weak. The world comes in shades of "good" or "bad"; and

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precious little in it is neutral. Moreover, in relation both to the evolutionarily set stimuli and to those stimuli which are acquired, a lifetime of experience is continually remodeling their "competence," revising their power to trigger emotions. In other words, neither innate nor acquired stimuli are fixedly competent. They can be more or less competent over time, which really means that their ability to cause emotions is in part a function of how our lives have been lived. They change as a function of the individual's autobiography.

Does the notion that emotions can be triggered nonconsciously and automatically deny the classical notion of an "appraisal" phase preceding emotions? Not at all. The process by which, at a given moment, an object or situation *becomes* an emotionally competent stimulus often includes a conscious, cognitive appraising of the circumstances. Besides, even when the process is nonconscious, the current context may play a role and enhance or reduce the competence of the stimulus. In the end, the emotional competence of a given stimulus depends on several major factors: evolutionary history; personal history; and current context. In some instances, the same stimulus may cause virtually the same emotion for a lifetime; in other instances, the emotional competence varies over time. In other words, it is not true that emotions, conceived in the manner outlined here, are necessarily stereotyped and genetically set reactions. The machinery that produces the responses is genetically set, for certain, but past individual experience and current context can modulate the evolutionary wisdom to a greater or smaller degree.

The emotionally competent stimulus produces its action by activating certain brain regions that in my framework I designate as *triggering* or *induction* regions. The activity of those regions leads to the *execution* of the emotion. Once the emotion cascade is triggered and its execution begins, the emotional responses target both the body and other regions of the brain that are not part of the triggering set of regions. The responses alter the state of the internal milieu (using, for example, hormonal messages disseminated in the bloodstream); the state of the viscera; the state of the musculoskeletal system; and they lead a body now prepared by all these functional changes into carrying out varied actions or complex behaviors. The latter actions and behaviors range from facial and postural expressions to the acts that define, say, fight and flight behavior, or parenting, or sympathy; from *approach* to *withdrawal* behaviors; from behaviors we associate with the notion of *pleasure* and *reward* to behaviors we associate with the notion of *pain* and *punishment* or *aversion*. In the social context in which emotions often occur, the emotional state also alters the state of other individuals who perceive and react to that emotional state.

While the core of an emotion is the set of homeostasis-related bodily changes I just described, emotions involve changes in the brain itself. Along with the overt body changes there are subtle changes in the way the brain

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operates within those systems which support cognition, especially those which govern attention and mental image production. For example, sadness is often accompanied by a reduced rate of new image formation and by increased allotment of attention to those images. Happiness is often accompanied by the opposite circumstances: high rates of new image production and shorter attention spans. Moreover, as emotional states get established, a number of thoughts congruent with the emotion are also evoked. For example, the emotion of sadness provokes the recall of thoughts on the theme of loss and worthlessness, thoughts that are often referred to as "sad thoughts." They are sad thoughts by virtue of their association with the state of the body that defines sadness. In brief, even in this oversimplified description, an emotion is a complicated matter: a collection of preparatory body changes and ensuing behaviors that is accompanied by a particular style of mental operation.

Using the same perspective, how can we define feelings, specifically, feelings of emotion? My working definition of feelings indicates that *feelings are the mental representation of the physiologic changes that occur during an emotion*. The essence of feelings of emotion is the mapping of the emotional state in the appropriate body-sensing regions of the brain. But *feeling an emotion also includes the mapping of changes that occur in the cognitive processing style, as well as the evocation of thoughts that are congruent with the feeling state*.

In the broadest possible definition a feeling is the perception of an emotional state, as enacted in the body, an essential content of which is the perception of some variation of the sense of pleasure or pain (establishing a connection to the subset of reward and aversion mechanisms that are an integral part of emotive behavior). Along with the perception of body changes there is also a perception of a certain mode of thinking, and of thoughts with certain themes. Thus feeling depends on the perception of a changed body state alongside the perception of a certain style of mental processing and the production of thoughts with themes consonant with the emotion.

VARIETIES OF EMOTION

The definition of feelings offered above is quite specific and yet broad enough to encompass feelings from three classes of emotion: background emotions, primary emotions, and social emotions (so-called secondary emotions). The application of the definition to all three classes of emotion/feeling, however, raises intriguing issues, some of which deserve comment.

First, it is apparent that the emotions that are currently part of the rosters of the above categories are extremely varied in terms of their emotionally competent stimulus, their physiological profile, and the homeostatic

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benefits they bring to an organism, directly or indirectly. Second, there is no general agreement about what to include or leave out from such lists of emotions, although it is fair to say that there is a consensus regarding most of what is or is not currently judged to be an emotion. Third, not everyone would agree with the suggestion that those emotions whose status gathers a broad consensus fit the definition I offered above. The objections would revolve around the regulatory, homeostatic role of emotions. For example, while fear or disgust produce indisputable advantages for the emoting subject, the benefits of sadness or happiness are often doubted.

Fourth, applying the above definition in the case of social emotions – for example, applying it to pride or despair – raises understandable questions. Is it indeed the case that such emotions engage the body in a distinctive way? Are pride and despair significantly deployed in the body at all? Is it not the case that what counts when we feel proud or desperate are the thoughts that lead to pride and despair, as well as the thoughts that follow? What has the body got to do with such processes?

My answer to these questions is that the definitions of emotion and feeling that I provided earlier *do* apply, as stated, to pride and despair. The bodily mise-en-scène of pride and despair is indeed powerful and distinctive. Can one imagine mistaking the behavior of a person in a fit of pride from that of a person in the throes of despair? Not really. Not even bad actors manage to confuse the two. The facial mask and the bodily countenance are specific to each of these emotions, and that goes only for what we can see with the naked eye, and not for what the viscera and the internal milieu manage to contribute away from sight.

Do I have any doubt that thoughts about the circumstances surrounding episodes of pride and despair are an important aspect of the comprehensive experience of pride and despair? I do not. But I believe that thoughts about the circumstances surrounding episodes of fear or sadness cannot be dismissed either, or regarded as of lesser importance. The differences in these emotions, and there are differences, have to do with the subtlety of the emotional expression – fear and sadness, perhaps, are more obvious, more variegated than pride and despair – and with the setting, which is perhaps more importantly sociocultural in the case of pride and despair. The body-relatedness is not different, however, and the universality of these emotions/feelings comes from bodily expressions that cut across cultures and species – just consider, for example, the proud demeanor of the leading male in a troop of monkeys. I suspect the objection arises mostly when the "bodily basis" of feelings is conceived too narrowly, along the visceral dimension only. The inclusion of the extensive signaling from musculoskeletal and internal milieu processes addresses the objection.

Although it would not be possible for me to agree to a definition of, say, pride or despair that would not factor body-specific components, I would be sympathetic to the argument if it were cast in the following

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manner: that although there is considerable evidence for a body component to social emotions, there is not enough empirical data showing that, say, pride and despair have entirely distinct profiles across a wide number of physiological parameters; I would agree that the strong view implied by my provisional definitions should not be regarded as definitely proven but rather as plausible and supported by preliminary evidence. In the end, however, when someone says that he or she feels proud but that someone believes the process of that feeling consists exclusively of thoughts about the circumstances surrounding the episode of pride, I suggest that the person does not "feel" pride at all, but rather "thinks" pride. If feeling sad or desperate or happy is a mere matter of thoughts about circumstances, then the appropriate description is "thinking" sadly or desperately or happily. Why use the term "feeling" at all? Depriving an emotion or a feeling of their body-related components empties out their respective concepts.

That emotions and feelings are enmeshed with nonemotional mental events is quite apparent. That the human importance of emotions and feelings comes in great part from those other mental events with which they become associated is just as obvious. But the specifics of our understanding of the neurophysiology of emotion reside in elucidating the mechanisms that permit the realization of an emotional state and of the ensuing feeling, rather than with the mental events that bracket those mechanisms as either competent causes or consequences.

THE NEURAL BASIS FOR EMOTION AND FEELING

The composition of the neural systems involved in the production of emotion is being identified as a result of studies in humans and animals. The identification of these systems and of their key components has barely begun. For example, an emotionally competent stimulus, actual or recalled, consciously or nonconsciously appraised, is processed in sensory regions and results in the availability of neural signals at a variety of sites from which emotions can be triggered. Such sites include the amygdala and the ventromedial frontal cortices, which thus operate as interfaces between the appraisal process – the "gathering" of an emotionally competent stimulus – and the actual execution of an emotion. Sites such as the amygdala are part of multi-region systems that trigger emotions. On the other hand, sites in the hypothalamus, the basal forebrain (e.g., the nucleus accumbens), and in the brainstem (e.g., the nuclei in the periaqueductal gray), are the principal executors of an emotion. These are the structures that directly signal, chemically and neurally, to the body and brain targets whose changes will come to constitute an emotional state.

It is possible that some regions that operate as triggering sites also contribute to the execution of emotions (some nuclei in the amygdala), while other regions probably operate exclusively as effectors (the ventromedial

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prefrontal cortices). Only further empirical work will tell. However, none of the triggering/effector regions is likely to participate in the process that follows on the heels of an emotion, namely, feeling.

What can we currently say about the neural basis for the experiencing of emotions? Recent functional imaging studies show that body-sensing areas such as the somatosensory cortices of the insula and of the second somatosensory region (S2), the cingulate cortex, and some nuclei in the brainstem tegmentum, show a significant pattern of activation or deactivation when normal individuals experience the emotions of sadness, happiness, fear, and anger, and that, moreover, the patterns vary among the emotions. Of all regions receiving body signals the insula now appears to be the key cortical component in the process of feeling. Intriguingly, the insula receives signals from the bulk of the viscera and internal milieu conveyed by dedicated peripheral nerve systems, spinal cord and brainstem pathways, and even a specific thalamic nucleus. In brief, the recent findings indicate that the mapping of body states is significantly modified during the process of feeling an emotion and that those patterns of activation and deactivation are correlates of the mental states we call feelings.

The important notion to emphasize here is that the neural patterns exhibited in these regions are the substrate for the mental patterns we call feelings. This fact leads to an important question that must be raised at this point: how do the neural patterns in body-sensing regions arise in the first place? In my answer I propose three possible mechanisms.

The basic mechanism is the result of a straightforward mapping of body changes. The areas these studies identify are the recipients of signals hailing from the body, as changed by the emotional state. Just as emotion is produced by chemical and neural signals, so feelings too are based on chemical and neural signaling. In this first mechanism the chemical signals arrive at regions such as the area postrema, in the brainstem, and from there neural signals carry on the message inside the brain; the neural signals arrive at every segment of the spinal cord and also at the level of the brainstem via cranial nerves.

The second mechanism is a variant of the first. As a result of interference with signal processing, the information conveyed from the body is modulated at sites such as the spinal cord and brainstem, resulting in a particular map of the body state that takes into account the context of the organism and that varies to a smaller or larger degree from the map of the actual body state.

The third mechanism, which I have termed the "as-if-body-loop," produces, in its pure form, a neural map of the body state "as-if" it were occurring in the body, without the body being fully involved or involved at all in its actual execution. It is in effect a "simulation" and is probably akin to "mirror-neuron mechanisms" described more recently. Whether

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based fully or partly on the body, however, the body-relatedness of the maps that underlie feelings is the key issue.

The notion that the neural basis of feelings would be out of scientific reach is no longer tenable. The mental events we call feelings are associated with changes in the neural mapping of the body state. The finding of such correlations is the beginning of the unraveling of the neurophysiological mysteries behind one of the most critical aspects of human experience. We now know where to look further for the sort of changes – cellular and molecular – that provide the deeper underpinning of feelings. I note, however, that the success of this new stage of understanding of the physiology of affective phenomena depends on the research distinction between emotion and feeling I outlined above. The majority of emotional responses are directly observable either with the naked eye or with the appropriate scientific probes, for example, endocrine assays, psychophysiological and neurophysiological measurements. Emotional responses are perfectly objective, and emotions can be investigated in the numerous laboratory species that exhibit them, namely Drosophila, Aplysia, and rodents. The idea that they are subjective is an artifact of the improper conceptualization of the phenomena, in fact, a result of confusing objective emotions with subjective feelings. Emotions are *not* subjective, *not* private, *not* elusive, *not* intangible, *not* indefinable. Their neurobiology can be investigated objectively, and understanding their neurobiology opens the way to elucidating the neurobiology of feelings.

WHAT ARE EMOTIONS AND FEELINGS FOR?

The general role of emotions has been apparent for some time. For obvious reasons the role of feelings has been less clear or in dispute. Emotions allow organisms to cope successfully with a variety of objects and situations that are potentially dangerous or potentially advantageous. This is true of fear and disgust, of sadness and happiness, of sympathy and love, of shame and pride. The directness of the effect does vary immensely – the results of fear or disgust are immediate and pertain to the subject having the emotion; the results of sympathy or shame are often delayed and also involve others; the same is true of happiness, in many instances. Emotions are just the most visible and complex part of a tall edifice of biological regulation that includes basic homeostatic reactions, (e.g., those which maintain one's metabolism); basic reflexes; pain and pleasure behaviors; and appetitive drives and motivations.

Whereas emotions provide an immediate reaction to certain challenges and opportunities faced by an organism, feeling the emotions provides the organism with a mental alert for the significance of the object that caused the emotion and for the thoughts consequent to responding emotionally. The adaptive value of feelings comes from amplifying the mental impact

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of a given situation and increasing the probabilities that comparable situations can be anticipated and planned for in the future so as to avert risks and take advantage of opportunities.

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https://doi.org/10.1017/CBO9780511806582.004 Published online by Cambridge University Press