EMOTION

(from lat. e-motio, movement)

Emotion is a complex psychological phenomenon which occurs as animals or people live their lives. Emotions involve physiological arousal, appraisal of the situation, expressive behaviours, and conscious experience. Emotion is associated with feeling, mood, temperament, personality, disposition, and motivation.

The subjective feelings and associated physiological states known as emotions are essential features of normal human experience. Moreover, some of the most devastating psychiatric problems involve emotional (affective) disorders. Although everyday emotions are as varied as happiness, surprise, anger, fear, and sadness, they share some common characteristics: All emotions are expressed through both visceral motor changes and stereotyped somatic motor responses, especially movements of the facial muscles. These responses accompany subjective experiences that are not easily described, but which are much the same in all human cultures. Emotional expression is closely tied to the visceral motor system, and therefore entails the activity of all of the central brain structures that govern the preganglionic neurons in the brainstem and spinal cord. Historically, the neural centers that coordinate emotional responses have been grouped under the rubric of the limbic system. More recently, however, several brain regions in addition to the classical limbic system have been shown to play a pivotal role in emotional processing, including the amygdala and several cortical areas in the orbital and medial aspects of the frontal lobe. This broader constellation of cortical and subcortical regions encompasses not only the central components of the visceral motor system but also regions in the forebrain and diencephalon that motivate lower motor neuronal pools concerned with the somatic expression of emotional behavior. Effectively, the concerted action of these diverse brain regions constitutes an emotional motor system.

BASIC EMOTIONS

(common both for animals and humans)

stimulus event	cognition	feeling state	overt behavior	effect
threat	"danger"	fear	escape	safety
obstacle	"enemy"	anger	attack	destroy obstacle
gain of valued object	"possess"	joy	retain or repeat	gain resources
loss of valued object	"abandonment"	sadness	cry	reattach to lost object
member of one's group	"friend"	acceptance	groom	mutual support
unpalatable object	"poison"	disgust	vomit	eject poison
new territory	"examine"	expectation	map	knowledge of territory
unexpected event	"what is it?"	surprise	stop	gain time to orient

You don't need to learn by heart this slide, just notice what types of emotions exist and how they can be grouped (positive, negative, ambient).

HIGHER EMOTIONS (only humans)

- Intellectual (e.g. curiousness)
- Moral (e.g. timidity, altruism)
- Esthetical (e.g. style)

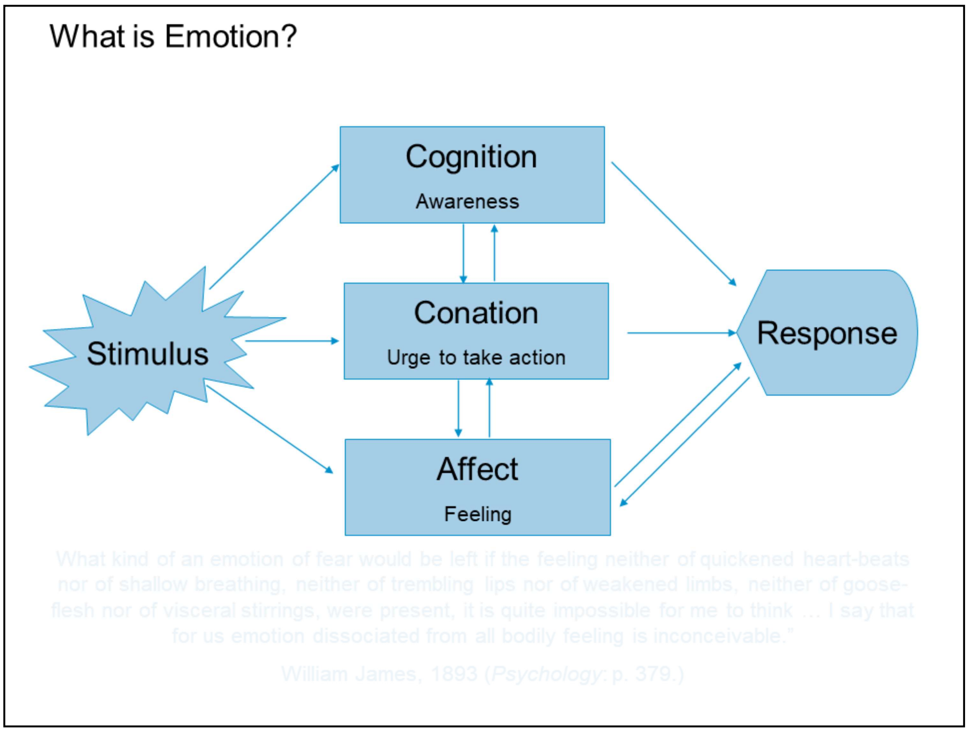
RELATIONSHIPS (combination of emotions)

- love
- friendship
- hatred
- envy
- jealousy

BODILY FEELINGS

- pain
- fatigue
- hunger
- thirst
- sexual desire(s)

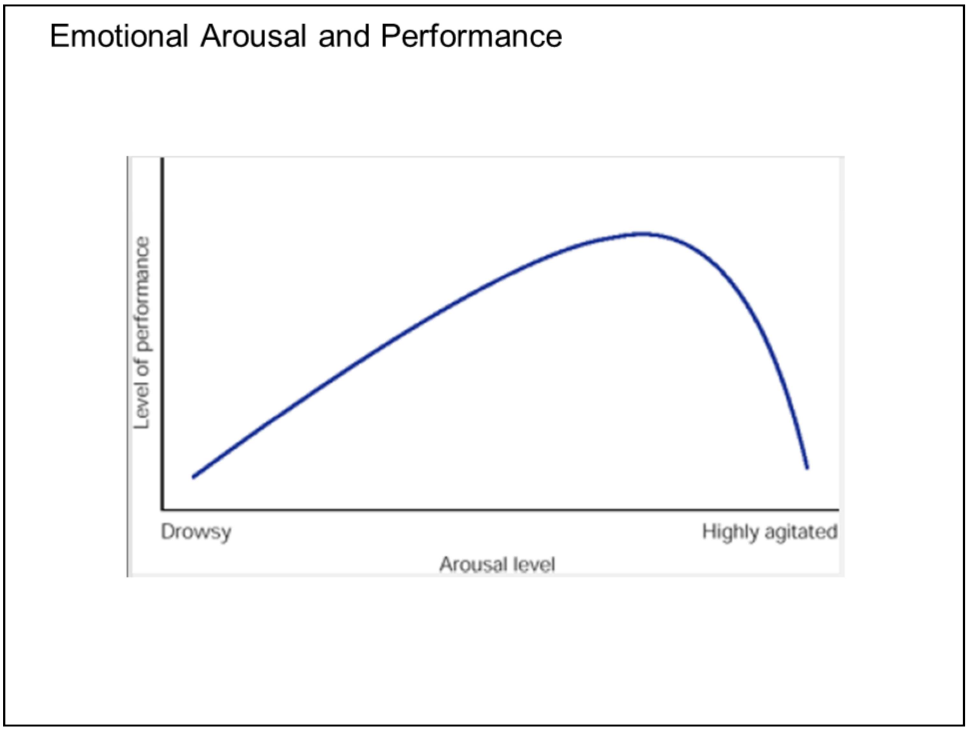
In humans, not only basic emotions, but also higher emotions can be observed and combinations of emotions – s.-c. relationships. Emotions are usually accompanied by various bodily feelings, frequently unpleasant (pain, fatigue, etc.).



The most obvious signs of emotional arousal involve changes in the activity of the visceral motor (autonomic) system. Thus, increases or decreases in heart rate, cutaneous blood flow (blushing or turning pale), piloerection, sweating, and gastrointestinal motility can all accompany various emotions. These responses are brought about by changes in activity in the sympathetic, parasympathetic, and enteric components of the visceral motor system, which govern smooth muscle, cardiac muscle, and glands throughout the body. Intense activity of the sympathetic division of the visceral motor system prepares the animal to fully utilize metabolic and other resources in challenging or threatening situations. Conversely, activity of the parasympathetic division (and the enteric division) promotes a building up of metabolic reserves. The natural opposition of the expenditure and storage of resources is reflected in a parallel opposition of the emotions associated with these different physiological states. “The desire for food and drink, the relish of taking them, all the pleasures of the table are naught in the presence of anger or great anxiety.” (W. Canon).

Activation of the visceral motor system, particularly the sympathetic division, was long considered an all-or-nothing process. Once effective stimuli engaged the system, it was argued, a widespread discharge of all of its components ensued. More recent studies have shown that the responses of the autonomic nervous system are actually quite specific, with different patterns of activation characterizing different situations and their associated emotional states. Indeed, emotion-specific expressions produced voluntarily can elicit distinct patterns of autonomic activity. For example, if subjects are given muscle-by-muscle instructions that result in facial expressions recognizable as anger, disgust, fear, happiness, sadness, or surprise without being told which emotion they are simulating, each pattern of facial muscle activity is accompanied by specific and reproducible differences in visceral motor activity (as measured by indices such as heart rate, skin conductance, and skin temperature). Moreover, autonomic responses are strongest when the facial expressions are judged to most closely resemble actual emotional expression and are often accompanied by the subjective experience of that emotion! One interpretation of these findings is that when voluntary facial expressions are produced, signals in the brain engage not only the motor cortex but also some of the circuits that produce emotional states. Perhaps this relationship helps explain how good actors can be so convincing. Nevertheless, we are quite adept at recognizing the difference between a contrived facial expression and the spontaneous smile that accompanies a pleasant emotional state.

This evidence, along with many other observations, indicates that one source of emotion is sensory drive from muscles and internal organs. This input forms the sensory limb of reflex circuitry that allows rapid physiological changes in response to altered conditions. However, physiological responses can also be elicited by complex and idiosyncratic stimuli mediated by the forebrain. For example, an anticipated tryst with a lover, a suspenseful episode in a novel or film, stirring patriotic or religious music, or dishonest accusations can all lead to autonomic activation and strongly felt emotions. The neural activity evoked by such complex stimuli is relayed from the forebrain to autonomic and somatic motor nuclei via the hypothalamus and brainstem reticular formation, the major structures that coordinate the expression of emotional behavior.

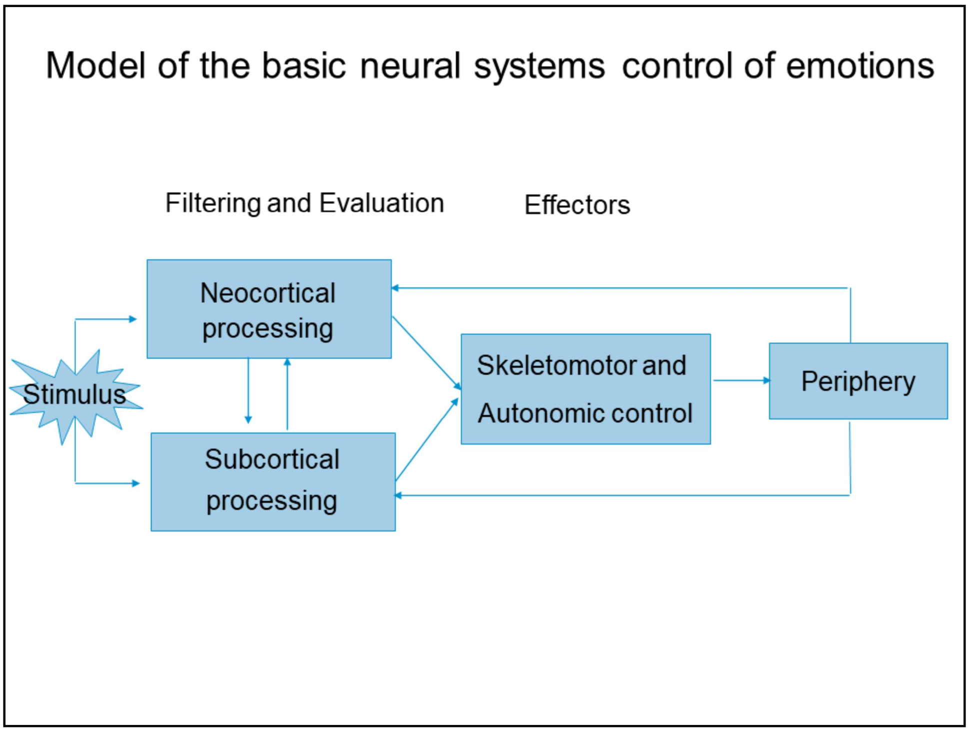


Performance is affected by arousal level. An intermediate level of arousal is optimal; performance is less adequate at both very high and very low levels of arousal.

The Peripheral Components of Emotion Prepare the Body for Action and Communicate Our Emotional States to Other People

The peripheral, skeletomotor and autonomic aspects of emotion have preparatory and communicative functions. The preparatory function involves both *general arousal*, which prepares the organism as a whole for action, and *specific arousal*, which prepares the organism for a particular behavior. For example, sexual arousal involves an increase of heart rate, a change that prepares the organism generally for physical exertion. In addition, it involves more localized changes, such as tumescence, that are specific to sexual behavior. The mechanisms of generalized and specific arousal act synergistically to prepare the periphery (muscles, glands, blood vessels) and the cerebral cortex for ongoing or upcoming events. Unless it is extreme, arousal enhances intellectual and physical performance.

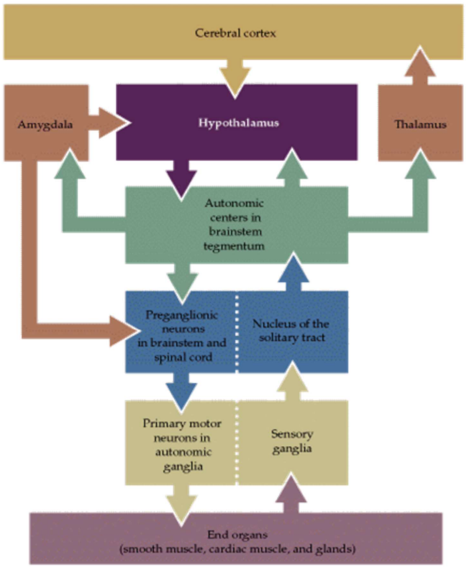
The peripheral component of emotion also communicates emotion to others. In humans social communication of emotion is mediated primarily by the skeletomotor system, in particular by the muscles that control facial and postural expressions.

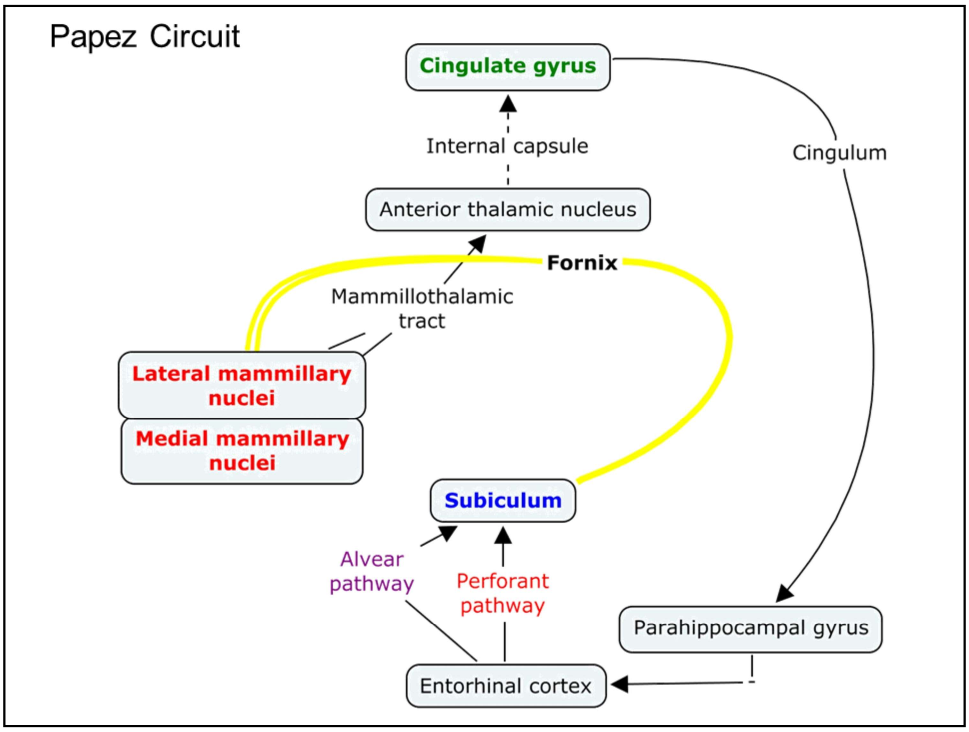


Emotions are typically elicited by a specific stimulus. The stimulus affects both neocortical anc subcortical structures, such the amygdala. In turn, cortical structures and the amygdala and othe subcortical structures regulate the systems that mediate the peripheral manifestations of emotiona behaviors. The particular emotion experienced is a function of cross-talk between neocortical anc subcortical structures, as well as feedback from peripheral receptors.

Conscious feeling is mediated by the cerebral cortex, in part by the cingulate cortex and by the fronta lobes. Emotional states are mediated by a family of peripheral, autonomic, endocrine, anc skeletomotor responses. These responses involve subcortical structures: the amygdala, the hypothalamus, and the brain stem. When frightened we not only feel afraid but also experience increased heart rate and respiration, dryness of the mouth, tense muscles, and sweaty palms, all o which are regulated by subcortical structures. To understand an emotion such as fear we therefore need to understand the relationship between cognitive feeling represented in the cortex and the associated physiological signs orchestrated in subcortical structures.

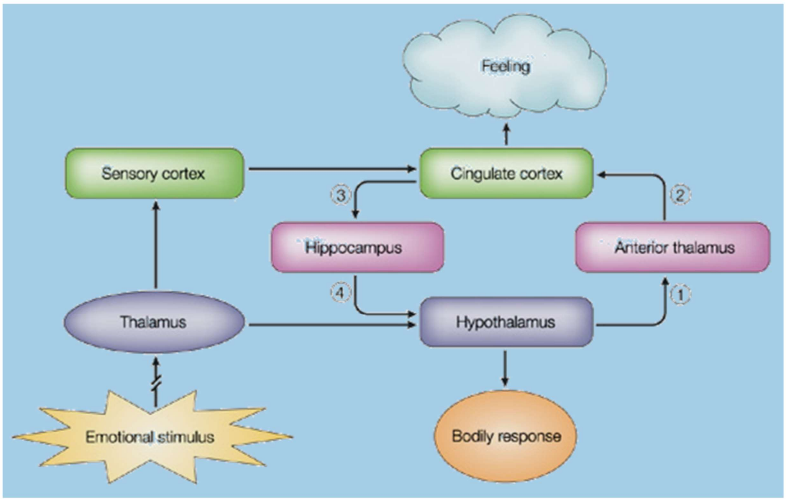
Hypothalamic control of ANS





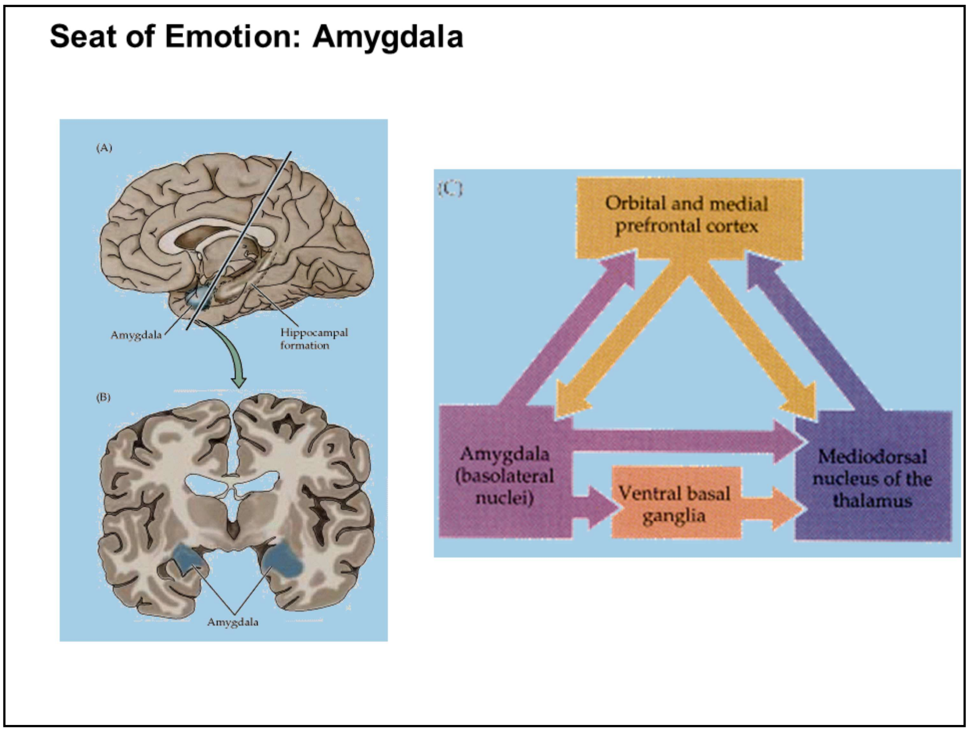
For many years, these structures, along with the olfactory bulbs, were thought to be concerned primarily with the sense of smell. Papez, however, speculated that the function of the limbic lobe might be more related to the emotions. He knew from the work of Bard and Hess that the hypothalamus influences the expression of emotion; he also knew, as everyone does, that emotions reach consciousness, and that higher cognitive functions affect emotional behavior. Ultimately, Papez showed that the cingulate cortex and hypothalamus are interconnected via projections from the mammillary bodies (part of the posterior hypothalamus) to the **anterior nucleus of the dorsal thalamus**, which projects in turn to the cingulate gyrus. The cingulate gyrus (and a lot of other cortex as well) projects to the hippocampus. Finally, he showed that the hippocampus projects via the fornix (a large fiber bundle) back to the hypothalamus. Papez suggested that these pathways provided the connections necessary for cortical control of emotional expression, and they became known as the “Papez circuit.

Papez Circuit of Emotional Response



Papez argued that sensory messages concerning emotional stimuli that arrive at the thalamus are then directed to both the cortex (stream of thinking) and the hypothalamus (stream of feeling). Papez proposed a series of connections from the hypothalamus to the anterior thalamus (1) and on to the cingulate cortex (2). Emotional experiences or feelings occur when the cingulate cortex integrates these signals from the hypothalamus with information from the sensory cortex. Output from the cingulate cortex to the hippocampus (3) and then to the hypothalamus (4) allows top–down cortical control of emotional responses.

Papez argued that, since the hypothalamus communicates reciprocally with areas of the cerebral cortex, information about the conscious and peripheral aspects of emotion affect each other. Papez proposed that the neocortex influences the hypothalamus by means of connections to the cingulate gyrus and from the cingulate gyrus to the hippocampal formation. According to this idea, the hippocampal formation processes information from the cingulate gyrus and conveys it to the mammillary bodies of the hypothalamus by way of the fornix (a fiber bundle that carries part of the outflow of the hippocampus). In turn, the hypothalamus provides information to the cingulate gyrus by a pathway from the mammillary bodies to the anterior thalamic nuclei (the mammillothalamic tract) and from there to the cingulate gyrus. Consistent with this idea is the clinical observation that patients who have been infected with the rabies virus—which characteristically attacks the hippocampus—show profound changes in emotional state, including bouts of terror and rage.



(A) **Sagittal view of the brain, illustrating the location of the amygdala in the temporal lobe. The line indicates the level of the section in (B). (B) Coronal section through the forebrain at the level of the amygdala.**

(B) **(C) Connections between the amygdala (specifically, the basolateral group of nuclei) and the orbital and medial prefrontal cortex. The amygdala participates in a "triangular" circuit linking the amygdala, the thalamic mediodorsal nucleus (directly and indirectly via the ventral parts of the basal ganglia), and the orbital and medial prefrontal cortex. These complex interconnections allow direct interactions between the amygdala and the prefrontal cortex, as well as indirect modulation via the circuitry of the ventral basal ganglia.**

The Amygdala Is the Part of the Limbic System Most Specifically Involved With Emotional Experience

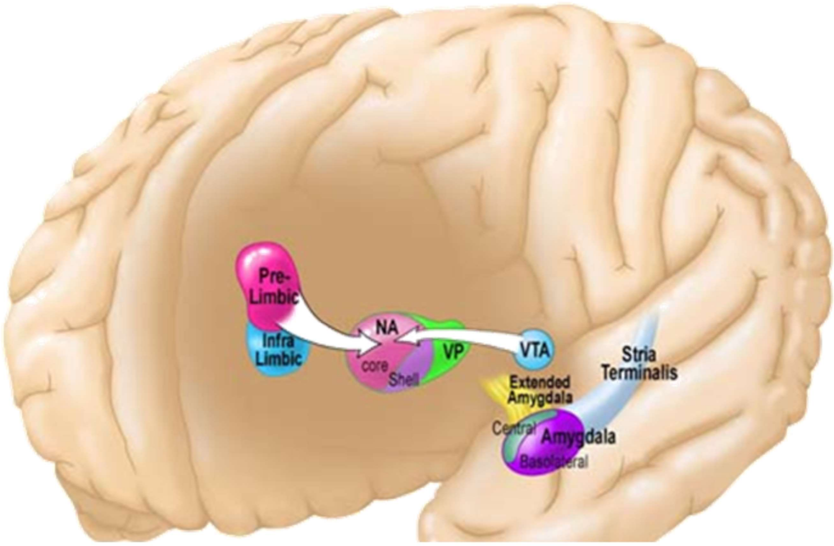
Considerable evidence from both humans and experimental animals now indicates that the amygdala rather than the hippocampus intervenes between the regions concerned with the somatic expression of emotion (the hypothalamus and the brain stem nuclei) and the neocortical areas concerned with conscious feeling, especially fear (the cingulate, parahippocampal, and prefrontal cortices).

For example, electrical stimulation of the amygdala in humans produces feelings of fear and apprehension. Conversely, damage to the amygdala in experimental animals produces tameness. These results suggest that there are two anatomically separate neural systems. One, located in the inferotemporal cortex, is involved in the explicit memory of facial identity. The other, located in the amygdala, is concerned with the implicit memory of the appropriate cues that signal emotions expressed by faces.

How does the amygdala participate in forming an emotional response to visual stimuli? Appropriate responses to the sight of emotionally charged signals are coded by the inferior temporal cortex. Neurons in the inferior temporal cortex respond to facial features, including the direction of gaze. Lesions in this area impair the ability to discriminate the direction of gaze in other faces. Since the amygdala receives input from the inferior temporal cortex and has strong connections to the autonomic nervous system, it can mediate emotional responses to complex visual stimuli.

As Charles Darwin first pointed out in 1872, fearful, angry, and happy facial expressions are virtually universal and have not only personal but social significance. Indeed, the recognition of facial expressions is essential for successful social behavior in a complex social environment. Thus, the behavioral impairments resulting from damage to the amygdala suggest that the amygdala may be important for social cognition.

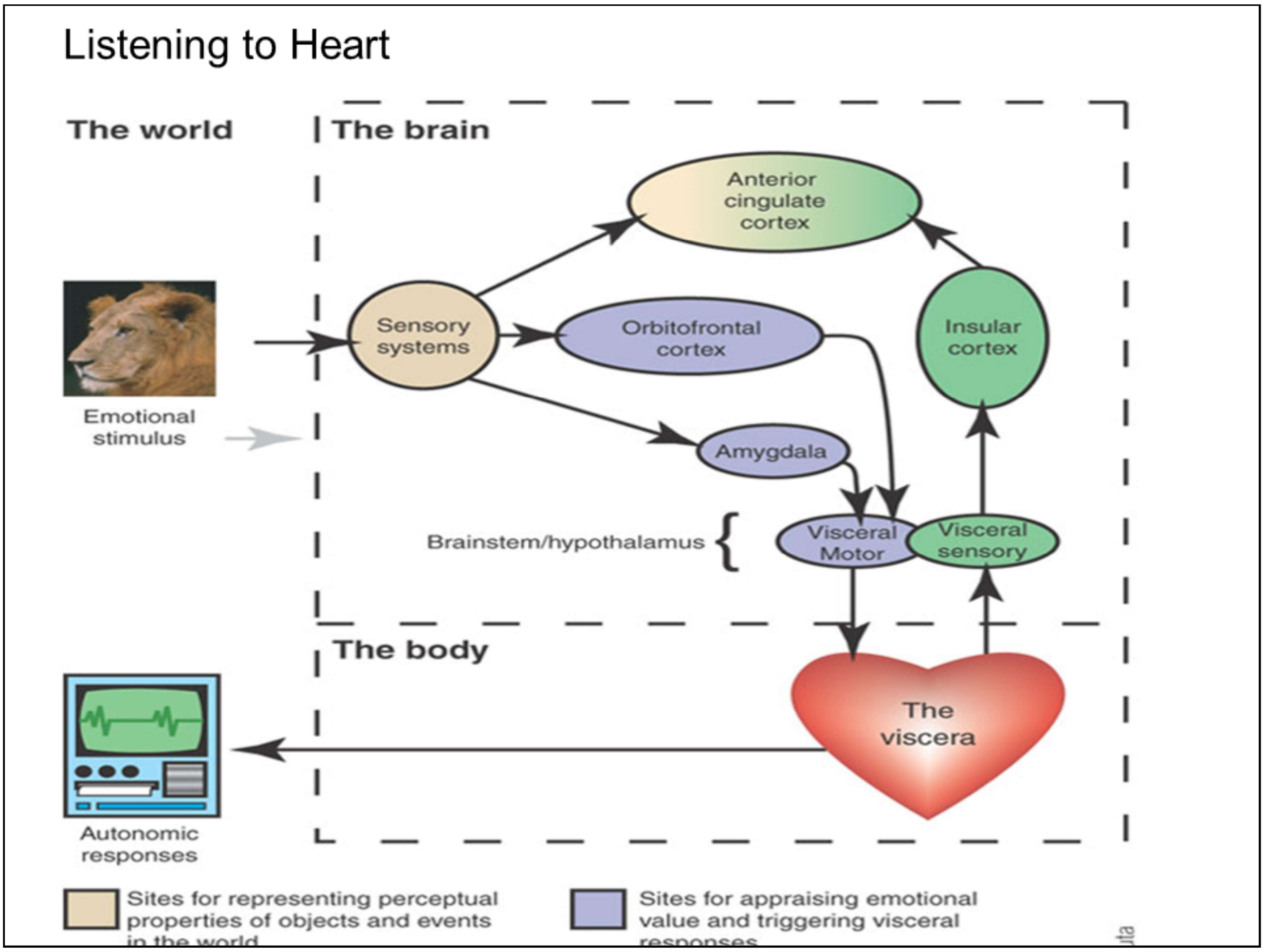
The Amygdala May Be Involved in Both Pleasurable and Fearful Responses to Stimuli



In addition to its role in fear and other negative emotional reactions, the amygdala may also play a role in pleasure or other appetitive, emotional reactions. When a neutral discriminative stimulus such as a tone is paired with a positive reinforcing stimulus such as food, the tone can become associated either with rewarding attributes of the food (its taste) or with nonrewarding attributes (its visual appearance). Lesions of the basolateral nuclei leave intact the learned association between the tone and the nonrewarding aspects of the food, but they disrupt the association of the tone with rewarding attributes of the food.

Finally, the amygdala is required for a type of learning termed *context conditioning*, (or *place-preference)* by which an animal learns to increase its contact with environments in which it has previously encountered stimuli essential for survival and to minimize contact with environments that are aversive or dangerous. The positive preferences for place can be conditioned not only to food or sexual partners but also to drugs, such as stimulants.

Place preference can be used to measure the rewarding properties of stimuli ranging from simple rewards (sweets) to complex ones (sexual partners). The constellation of stimuli that make up the distinctive environment in which a reward is obtained becomes associated with the reward. As a result, these *place cues* later take on positive values and increase the likelihood that the animal will again seek out this place and maintain contact with it, even in the absence of the primary reward. Presumably, place cues gain positive properties in part by means of classical conditioning. There is considerable evidence that the amygdala, particularly the basolateral complex, which integrates incoming sensory input, is involved in associating place cues with reward value. Contextual conditioning also involves acquiring and binding together a variety of sensory information about place, a process that requires the hippocampus.



The emotional stimulus is represented in one or more of the brain's sensory processing systems

This information, which can be derived from the environment or recalled from memory, is made available to the amygdala and orbitofrontal cortex, which are trigger sites for emotion. The sites of emotion execution include the hypothalamus, the basal forebrain and nuclei in the brainstem tegmentum. Only the visceral response is represented, although emotion includes endocrine and somatomotor responses as well. Visceral sensations reach the anterior insular cortex by passing through the brainstem. Feelings result from the re-representation of changes in the viscera in relation to the object or event that initiated them. The anterior cingulate cortex is a site of this second-order mapping.

The Interplay of Emotion and Reason

The experience of emotion—even on a subconscious level—has a powerful influence on the neural faculties responsible for making rational decisions. Evidence for this statement has come principally from studies of patients with damage to parts of the orbital and medial prefrontal cortex, as well as patients with injury or disease involving the amygdala (see Box D). Such patients have in common an impairment in emotional processing, especially emotions engendered by complex personal and social situations, and an inability to make advantageous decisions.

Experimental studies of fear conditioning have suggested just such a linking role for the amygdala in associating sensory stimuli with aversive consequences. Indeed, the patient described in Box D showed an inability to recognize and experience fear, together with impairment in rational decision making. Similar evidence of the emotional influences on decision making have also come from studies of patients with lesions in the orbital and medial prefrontal cortex. These clinical observations suggest that the amygdala and prefrontal cortex, as well as their striatal and thalamic connections, are not only involved in processing emotions, but also participate in the complex neural processing responsible for what we consider rational thinking.

TAKE HOME MESSAGE

Summary

The word “emotion” covers a wide range of states that have in common the association of visceral motor responses, somatic behavior (e.g., facial expressions), and powerful subjective feelings. The visceral motor responses are mediated by the visceral motor nervous system, which is itself regulated by inputs from many other parts of the brain. The organization of the somatic motor behavior associated with emotion is governed by circuits in the limbic system, which includes the hypothalamus, the amygdala, and several regions of the cerebral cortex. Although a good deal is known about the neuroanatomy and transmitter chemistry of the different parts of the limbic system, there is still a dearth of information about how this complex circuitry mediates specific emotional states. Similarly, neuropsychologists and neurologists are only now coming to appreciate the important role of emotional processing in other complex brain functions, such as decision making. A variety of other evidence indicates that the two hemispheres are differently specialized for the governance of emotion, the right hemisphere being the more important in this regard. The prevalence and social significance of human

emotions and their disorders ensure that the neurobiology of emotion will be an increasingly important theme in modern neuroscience.