FUNDAMENTALS OF COGNITIVE NEUROSCIENCE

A BEGINNER'S GUIDE

SECOND EDITION

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humans implicate the amygdala and the activation of β-adrenergic stress hormone systems during and after the emotional experience and memory formation. In a now-classic study, Cahill and colleagues (Cahill, Prins, Weber, & McGaugh, 1994) investigated the memory for an emotionally arousing story and an emotionally neutral story in human subjects who were assigned randomly to one of two experimental groups: placebo—with no medication given, and propranolol—with a dose of propranolol hydrochloride given, which is a β-adrenergic receptor antagonist or β-blocker. Subjects in both groups viewed a slide show of either an *emotionally arousing story* or an *emotionally neutral story*. All subjects' memories for the stories' events was tested 1 week later. Findings showed that all subjects—in both the placebo and the propranolol groups—performed similarly, on a memory test 1 week later for the emotionally neutral story. However, for the emotionally arousing story, the subjects in the propranolol showed much poorer memory than the subjects in the placebo group.

Cahill and colleagues interpreted these findings with human subjects, along with previous work with animals, as supporting the hypothesis that the emotional memory storage is modulated by β-adrenergic systems and further that these systems are not implicated in storage of emotionally neutral information or memories. These early findings have been well supported by more recent studies; however, a follow-up investigation by Cahill and colleagues (Cahill, Uncapher, Kilpatrick, Alkire, & Turner, 2004) has shed new light on the role of the amygdala in emotional memory processing: in an fMRI study of human subjects viewing pictures that varied in their emotional arousing ratings from tranquil to highly arousing. The amygdala region was activated by the arousing pictures, as hypothesized, but the central finding of the study was a strong *sex × hemisphere* interaction. For men, the *right hemisphere amygdala* was more activated for the emotional pictures; however, for the women, the *left hemisphere amygdala* was more activated (Fig. 11.18). This result has been replicated and reproduced by other experimenters—providing important new data about sex differences in the brain bases of emotional processing.

Reliving happy memories, including feelings of emotional arousal, can be a pleasant experience. However, when frightening or horrifying memories are reexperienced, along with the negative emotions felt when they were encoded, they can produce a life-altering state of stress and trauma. This is what happens in cases of posttraumatic stress disorder, or PTSD, discussed later in this chapter.

7. REWARDS AND MOTIVATION

When a behavior or a situation is highly rewarding to us, we tend to repeat that behavior or strive to have that situation occur again. If you are a chocolate lover, you do not need to be convinced that a bite of a brownie still warm from the oven sends you craving for more! This is a simplified explanation for how *reward* and *motivation* work together to influence behavior—we experience a *rewarding event* and this experience puts into place the *motivation to repeat the reward*…and if this reward is not able to be repeated, it may also begin a process of *craving for that reward*.

Brain pathways for this reward-inducing experience include the ventral tegmental area (VTA), the NAc, and the PFC (Laviolette & van der Kooy, 2004) (Fig. 11.19). Dopamine (DA) neurons from the VTA project to the NAc and PFC: this is a main *dopaminergic reward*

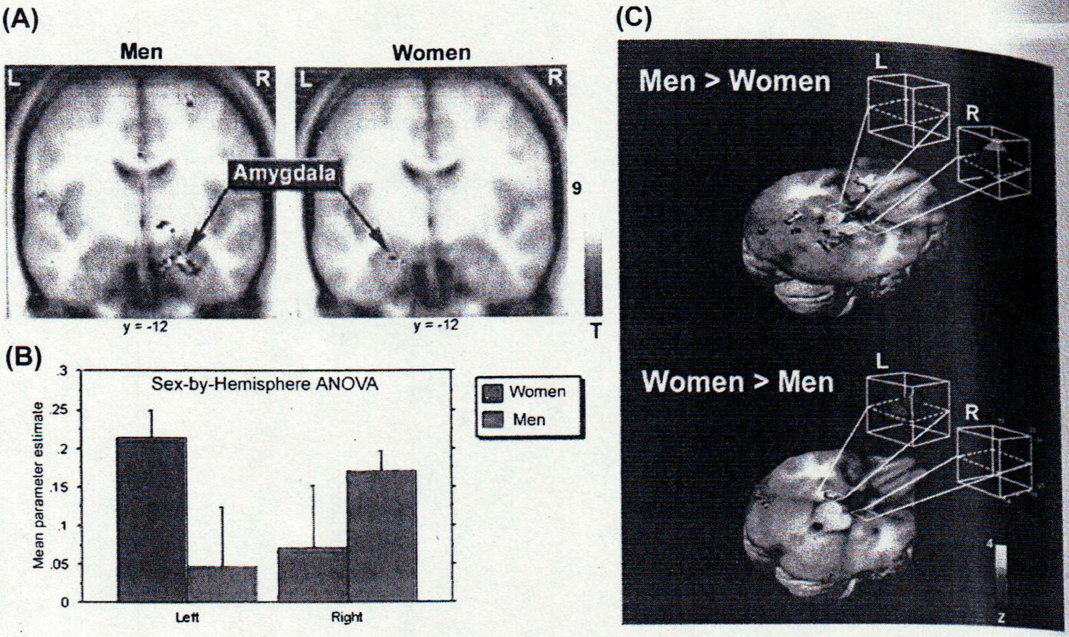

FIGURE 11.18 Cahill and colleagues investigated the activation of the amygdala in a functional magnetic resonance imaging (fMRI) study of human subjects viewing pictures that varied in their emotional arousing ratings from tranquil to highly arousing. The amygdala region was activated by the arousing pictures, as hypothesized, but the central finding of the study was a strong *sex × hemisphere* interaction. For men, the *right hemisphere amygdala* was more activated for the emotional pictures however, for the women, the *left hemisphere amygdala* was more activated. (A) A coronal view of the brain activity in the amygdala for the men in the study (left panel) and the women in the study (right panel). (B) Men and women showed a strong difference in amygdala activation. (C) Another view of the hemisphere asymmetry for men versus women in this study. This view shows coronal slices of the brain presented in a horizontal presentation. Shown in the small boxes is (top panel) the difference in activation for Men versus Women in the right amygdala and (bottom panel) the difference in activation for Women versus Men in the left amygdala. This result has been replicated and reproduced by other experimenters, providing important new data about sex differences in the brain bases of emotional processing. *Source: Cahill et al. (2004).*

signaling pathway. DA neurons from the VTA project to the PFC: this is the *mesocortical pathway*. They also project to the NAc: this is the *mesolimbic pathway*. Together, these two reward pathways are called the *mesocorticolimbic projection*. DA neurons' projections are shown in Fig. 11.20. DA neurons also innervate the amygdala and the hippocampus. GABA neurons can inhibit the DA projections. These DA and GABA pathways form a highly complex circuitry underlying our feelings of reward, motivation, and craving.

In addition to the naturally occurring rewarding experiences that produce DA, there are many other DA inducers: they include nicotine found in cigarettes, alcohol, and many drugs of abuse including cocaine. When these systems and pathways are functioning in a healthy way, they provide the brain bases for motivation and reward that influences our behavior in many positive ways. However, when these systems are altered or impaired, they can lead to addiction and mood disorders, discussed later in this chapter.