Brain anatomy

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Related References

LeDoux, J.. (2007). The amygdala. Current Biology

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“The amygdala is a complex rnstructure involved in a wide range rof normal behavioral functions and rpsychiatric conditions. not so long rago it was an obscure region of the brain that attracted relatively little scientific interest. today it is one of the most heavily studied brain areas, and practically a household word. art critics are explaining the impact of a painting by its direct impact on the amygdala; essential oils are said to alter mood by affecting the amygdala; and there is a website where you can unleash your creativity by clicking your amygdala, and thereby popping your frontal cortex. in this primer, i will focus on the scientific implications of the research, discussing the anatomical structure, connectivity, cellular properties and behavioral functions of the amygdala.”
Roozendaal, B., McEwen, B. S., & Chattarji, S.. (2009). Stress, memory and the amygdala. Nature Reviews Neuroscience

Plain numerical DOI: 10.1038/nrn2651
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“Emotionally significant experiences tend to be well remembered, and the amygdala has a pivotal role in this process. but the efficient encoding of emotional memories can become maladaptive — severe stress often turns them into a source of chronic anxiety. here, we review studies that have identified neural correlates of stress-induced modulation of amygdala structure and function — from cellular mechanisms to their behavioural consequences. the unique features of stress-induced plasticity in the amygdala, in association with changes in other brain regions, could have long-term consequences for cognitive performance and pathological anxiety exhibited in people with affective disorders.”
Davis, M., & Whalen, P. J.. (2001). The amygdala: Vigilance and emotion. Molecular Psychiatry

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“Here we provide a review of the animal and human literature concerning the role of the amygdala in fear conditioning, considering its potential influence over autonomic and hormonal changes, motor behavior and attentional processes. a stimulus that predicts an aversive outcome will change neural transmission in the amygdala to produce the somatic, autonomic and endocrine signs of fear, as well as increased attention to that stimulus. it is now clear that the amygdala is also involved in learning about positively valenced stimuli as well as spatial and motor learning and this review strives to integrate this additional information. a review of available studies examining the human amygdala covers both lesion and electrical stimulation studies as well as the most recent functional neuroimaging studies. where appropriate, we attempt to integrate basic information on normal amygdala function with our current understanding of psychiatric disorders, including pathological anxiety.”
Roy, A. K., Shehzad, Z., Margulies, D. S., Kelly, A. M. C., Uddin, L. Q., Gotimer, K., … Milham, M. P.. (2009). Functional connectivity of the human amygdala using resting state fMRI. NeuroImage

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“The amygdala is composed of structurally and functionally distinct nuclei that contribute to the processing of emotion through interactions with other subcortical and cortical structures. while these circuits have been studied extensively in animals, human neuroimaging investigations of amygdala-based networks have typically considered the amygdala as a single structure, which likely masks contributions of individual amygdala subdivisions. the present study uses resting state functional magnetic resonance imaging (fmri) to test whether distinct functional connectivity patterns, like those observed in animal studies, can be detected across three amygdala subdivisions: laterobasal, centromedial, and superficial. in a sample of 65 healthy adults, voxelwise regression analyses demonstrated positively-predicted ventral and negatively-predicted dorsal networks associated with the total amygdala, consistent with previous animal and human studies. investigation of individual amygdala subdivisions revealed distinct differences in connectivity patterns within the amygdala and throughout the brain. spontaneous activity in the laterobasal subdivision predicted activity in temporal and frontal regions, while activity in the centromedial nuclei predicted activity primarily in striatum. activity in the superficial subdivision positively predicted activity throughout the limbic lobe. these findings suggest that resting state fmri can be used to investigate human amygdala networks at a greater level of detail than previously appreciated, allowing for the further advancement of translational models. © 2008 elsevier inc. all rights reserved.”
Bechara, A., D., H., Damasio, A. R., & Lee, G. P.. (1999). Different contributions of the human amygdala and ventromedial prefrontal cortex to decision-making.. The Journal of Neuroscience : The Official Journal of the Society for Neuroscience

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“The somatic marker hypothesis proposes that decision-making is a process that depends on emotion. studies have shown that damage of the ventromedial prefrontal (vmf) cortex precludes the ability to use somatic (emotional) signals that are necessary for guiding decisions in the advantageous direction. however, given the role of the amygdala in emotional processing, we asked whether amygdala damage also would interfere with decision-making. furthermore, we asked whether there might be a difference between the roles that the amygdala and vmf cortex play in decision-making. to address these two questions, we studied a group of patients with bilateral amygdala, but not vmf, damage and a group of patients with bilateral vmf, but not amygdala, damage. we used the ‘gambling task’ to measure decision-making performance and electrodermal activity (skin conductance responses, scr) as an index of somatic state activation. all patients, those with amygdala damage as well as those with vmf damage, were (1) impaired on the gambling task and (2) unable to develop anticipatory scrs while they pondered risky choices. however, vmf patients were able to generate scrs when they received a reward or a punishment (play money), whereas amygdala patients failed to do so. in a pavlovian conditioning experiment the vmf patients acquired a conditioned scr to visual stimuli paired with an aversive loud sound, whereas amygdala patients failed to do so. the results suggest that amygdala damage is associated with impairment in decision-making and that the roles played by the amygdala and vmf in decision-making are different.”

Janak, P. H., & Tye, K. M.. (2015). From circuits to behaviour in the amygdala. Nature

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“The amygdala has long been associated with emotion and motivation, playing an essential part in processing both fearful and rewarding environmental stimuli. how can a single structure be crucial for such different functions? with recent technological advances that allow for causal investigations of specific neural circuit elements, we can now begin to map the complex anatomical connections of the amygdala onto behavioural function. understanding how the amygdala contributes to a wide array of behaviours requires the study of distinct amygdala circuits.”

Murray, E. A.. (2007). The amygdala, reward and emotion. Trends in Cognitive Sciences

Plain numerical DOI: 10.1016/j.tics.2007.08.013
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“Recent research provides new insights into amygdala contributions to positive emotion and reward.

studies of neuronal activity in the monkey amygdala and of autonomic responses mediated by the monkey amygdala show that, contrary to a widely held view, the amygdala is just as important for processing positive reward and reinforcement as it is for negative. in addition, neuropsychological studies reveal that the amygdala is essential for only a fraction of what might be considered ‘stimulus-reward processing’, and that the neural substrates for emotion and reward are partially nonoverlapping. finally, evidence suggests that two systems within the amygdala, operating in parallel, enable reward-predicting cues to influence behavior; one mediates a general, arousing effect of reward and the other links the sensory properties of reward to emotion.”
Baxter, M. G., Murray, E. A., & Hall, W. J.. (2002). The amygdala and reward. Nature Reviews. Neuroscience

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“The amygdala — an almond-shaped group of nuclei at the heart of the telencephalon — has been associated with a range of cognitive functions, including emotion, learning, memory, attention and perception. most current views of amygdala function emphasize its role in negative emotions, such as fear, and in linking negative emotions with other aspects of cognition, such as learning and memory. however, recent evidence supports a role for the amygdala in processing positive emotions as well as negative ones, including learning about the beneficial biological value of stimuli. indeed, the amygdala’s role in stimulus-reward learning might be just as important as its role in processing negative affect and fear conditioning.”
Baron-Cohen, S., Ring, H. A., Bullmore, E. T., Wheelwright, S., Ashwin, C., & Williams, S. C. R.. (2000). The amygdala theory of autism. Neuroscience and Biobehavioral Reviews

Plain numerical DOI: 10.1016/S0149-7634(00)00011-7
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“Brothers (brothers l. concepts in neuroscience 1990;1:27-51) proposed a network of neural regions that comprise the ‘social brain’, which includes the amygdala. since the childhood psychiatric condition of autism involves deficits in ‘social intelligence’, it is plausible that autism may be caused by an amygdala abnormality. in this paper we review the evidence for a social function of the amygdala. this includes reference to the kluver-bucy syndrome (which hetzler and griffin suggested may serve as an animal model of autism). we then review evidence for an amygdala deficit in people with autism, who are well known to have deficits in social behaviour. this includes a detailed summary of our recent functional magnetic resonance imaging (fmri) study involving judging from the expressions of another person’s eyes what that other person might be thinking or feeling. in this study, patients with autism or as did not activate the amygdala when making mentalistic inferences from the eyes, whilst people without autism did show amygdala activity. the amygdala is therefore proposed to be one of several neural regions that are abnormal in autism. we conclude that the amygdala theory of autism contains

promise and suggest some new lines of research. (c) 2000 elsevier science ltd."
Phelps, E. A., & LeDoux, J. E.. (2005). Contributions of the amygdala to emotion processing: From animal models to human behavior. Neuron

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"Research on the neural systems underlying emotion in animal models over the past two decades has implicated the amygdala in fear and other emotional processes. this work stimulated interest in pursuing the brain mechanisms of emotion in humans. here, we review research on the role of the amygdala in emotional processes in both animal models and humans. the review is not exhaustive, but it highlights five major research topics that illustrate parallel roles for the amygdala in humans and other animals, including implicit emotional learning and memory, emotional modulation of memory, emotional influences on attention and perception, emotion and social behavior, and emotion inhibition and regulation. copyright ©2005 by elsevier inc."
Maren, S., & Quirk, G. J.. (2004). Neuronal signalling of fear memory. Nature Reviews Neuroscience

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"The learning and remembering of fearful events depends on the integrity of the amygdala, but how are fear memories represented in the activity of amygdala neurons? here, we review recent electrophysiological studies indicating that neurons in the lateral amygdala encode aversive memories during the acquisition and extinction of pavlovian fear conditioning. studies that combine unit recording with brain lesions and pharmacological inactivation provide evidence that the lateral amygdala is a crucial locus of fear memory. extinction of fear memory reduces associative plasticity in the lateral amygdala and involves the hippocampus and prefrontal cortex. understanding the signalling of aversive memory by amygdala neurons opens new avenues for research into the neural systems that support fear behaviour."
LeDoux, J.. (2003). The emotional brain, fear, and the amygdala. Cellular and Molecular Neurobiology

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"1. considerable progress has been made over the past 20 years in relating specific circuits of the brain to emotional functions. much of this work has involved studies of pavlovian or classical fear conditioning, a behavioral procedure that is used to couple meaningless environmental stimuli to

emotional (defense) response networks. 2. the major conclusion from studies of fear conditioning is that the amygdala plays critical role in linking external stimuli to defense responses. 3. before describing research on the role of the amygdala in fear conditioning, though, it will be helpful to briefly examine the historical events that preceded modern research on conditioned fear."
Zald, D. H.. (2003). The human amygdala and the emotional evaluation of sensory stimuli. Brain Research Reviews

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"A wealth of animal data implicates the amygdala in aspects of emotional processing. in recent years, functional neuroimaging and neuropsychological studies have begun to refine our understanding of the functions of the amygdala in humans. this literature offers insights into the types of stimuli that engage the amygdala and the functional consequences that result from this engagement. specific conclusions and hypotheses include: (1) the amygdala activates during exposure to aversive stimuli from multiple sensory modalities; (2) the amygdala responds to positively valenced stimuli, but these responses are less consistent than those induced by aversive stimuli; (3) amygdala responses are modulated by the arousal level, hedonic strength or current motivational value of stimuli; (4) amygdala responses are subject to rapid habituation; (5) the temporal characteristics of amygdala responses vary across stimulus categories and subject populations; (6) emotionally valenced stimuli need not reach conscious awareness to engage amygdala processing; (7) conscious hedonic appraisals do not require amygdala activation; (8) activation of the amygdala is associated with modulation of motor readiness, autonomic functions, and cognitive processes including attention and memory; (9) amygdala activations do not conform to traditional models of the lateralization of emotion; and (10) the extent and laterality of amygdala activations are related to factors including psychiatric status, gender and personality. the strengths and weakness of these hypotheses and conclusions are discussed with reference to the animal literature. © 2002 elsevier science b.v. all rights reserved."
Swanson, L. W., & Petrovich, G. D.. (1998). What is the amygdala?. Trends in Neurosciences

Plain numerical DOI: 10.1016/S0166-2236(98)01265-X
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"'Amygdala' and 'amygdalar complex' are terms that now refer to a highly differentiated region near the temporal pole of the mammalian cerebral hemisphere. cell groups within it appear to be differentiated parts of the traditional cortex, the claustrum, or the striatum, and these parts belong to four obvious functional systems – accessory olfactory, main olfactory, autonomic and frontotemporal cortical. in rats, the central nucleus is a specialized autonomic-projecting motor region of the striatum, whereas the lateral and anterior basolateral nuclei together are a ventromedial extension of the claustrum for major regions of the temporal and frontal lobes. the rest of the amygdala forms association parts of the olfactory system (accessory and main), with cortical, claustral and striatal parts. terms such as 'amygdala' and 'lenticular nucleus' combine cell groups arbitrarily rather than according to the

structural and functional units to which they now seem to belong. the amygdala is neither a structural nor a functional unit.”
Adolphs, R., Tranel, D., Damasio, H., & Damasio, a R.. (1995). Fear and the human amygdala.. The Journal of Neuroscience : The Official Journal of the Society for Neuroscience

Plain numerical DOI: 10.1016/j.conb.2008.06.006
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“We have previously reported that bilateral amygdala damage in humans compromises the recognition of fear in facial expressions while leaving intact recognition of face identity (adolphs et al., 1994). the present study aims at examining questions motivated by this finding. we addressed the possibility that unilateral amygdala damage might be sufficient to impair recognition of emotional expressions. we also obtained further data on our subject with bilateral amygdala damage, in order to elucidate possible mechanisms that could account for the impaired recognition of expressions of fear. the results show that bilateral, but not unilateral, damage to the human amygdala impairs the processing of fearful facial expressions. this impairment appears to result from an insensitivity to the intensity of fear expressed by faces. we also confirmed a double dissociation between the recognition of facial expressions of fear, and the recognition of identity of a face: these two processes can be impaired independently, lending support to the idea that they are subserved in part by anatomically separate neural systems. based on our data, and on what is known about the amygdala’s connectivity, we propose that the amygdala is required to link visual representations of facial expressions, on the one hand, with representations that constitute the concept of fear, on the other. preliminary data suggest the amygdala’s role extends to both recognition and recall of fearful facial expressions.”
Kirsch, P.. (2005). Oxytocin Modulates Neural Circuitry for Social Cognition and Fear in Humans. Journal of Neuroscience

Plain numerical DOI: 10.1523/JNEUROSCI.3984-05.2005
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“In non-human mammals, the neuropeptide oxytocin is a key mediator of complex emotional and social behaviors, including attachment, social recognition, and aggression. oxytocin reduces anxiety and impacts on fear conditioning and extinction. recently, oxytocin administration in humans was shown to increase trust, suggesting involvement of the amygdala, a central component of the neurocircuitry of fear and social cognition that has been linked to trust and highly expresses oxytocin receptors in many mammals. however, no human data on the effects of this peptide on brain function were available. here, we show that human amygdala function is strongly modulated by oxytocin. we used functional magnetic resonance imaging to image amygdala activation by fear-inducing visual stimuli in 15 healthy males after double-blind crossover intranasal application of placebo or oxytocin. compared with placebo, oxytocin potently reduced activation of the amygdala and reduced coupling of the amygdala to brainstem regions implicated in autonomic and behavioral manifestations of fear. our results indicate a neural mechanism for the effects of oxytocin in social cognition in the human brain and provide a

methodology and rationale for exploring therapeutic strategies in disorders in which abnormal amygdala function has been implicated, such as social phobia or autism."
Phelps, E. A.. (2004). Human emotion and memory: Interactions of the amygdala and hippocampal complex. Current Opinion in Neurobiology

Plain numerical DOI: 10.1016/j.conb.2004.03.015
DOI URL
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"The amygdala and hippocampal complex, two medial temporal lobe structures, are linked to two independent memory systems, each with unique characteristic functions. in emotional situations, these two systems interact in subtle but important ways. specifically, the amygdala can modulate both the encoding and the storage of hippocampal-dependent memories. the hippocampal complex, by forming episodic representations of the emotional significance and interpretation of events, can influence the amygdala response when emotional stimuli are encountered. although these are independent memory systems, they act in concert when emotion meets memory."
Duvarci, S., & Pare, D.. (2014). Amygdala microcircuits controlling learned fear. Neuron

Plain numerical DOI: 10.1016/j.neuron.2014.04.042
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"We review recent work on the role of intrinsic amygdala networks in the regulation of classically conditioned defensive behaviors, commonly known as conditioned fear. these new developments highlight how conditioned fear depends on far more complex networks than initially envisioned. indeed, multiple parallel inhibitory and excitatory circuits are differentially recruited during the expression versus extinction of conditioned fear. moreover, shifts between expression and extinction circuits involve coordinated interactions with different regions of the medial prefrontal cortex. however, key areas of uncertainty remain, particularly with respect to the connectivity of the different cell types. filling these gaps in our knowledge is important because much evidence indicates that human anxiety disorders results from an abnormal regulation of the networks supporting fear learning. duvarci and pare review recent work on the role of intrinsic amygdala networks in regulating conditioned fear, revealing that it depends on multiple parallel inhibitory and excitatory circuits that are differentially recruited during the expression versus extinction of conditioned fear. © 2014 elsevier inc."
SAH, P., FABER, E. S. L., LOPEZ DE ARMENTIA, M., & POWER, J.. (2003). The Amygdaloid Complex: Anatomy and Physiology. Physiological Reviews

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“A converging body of literature over the last 50 years has implicated the amygdala in assigning emotional significance or value to sensory information. in particular, the amygdala has been shown to be an essential component of the circuitry underlying fear-related responses. disorders in the processing of fear-related information are likely to be the underlying cause of some anxiety disorders in humans such as posttraumatic stress. the amygdaloid complex is a group of more than 10 nuclei that are located in the midtemporal lobe. these nuclei can be distinguished both on cytoarchitectonic and connectional grounds. anatomical tract tracing studies have shown that these nuclei have extensive intranuclear and internuclear connections. the afferent and efferent connections of the amygdala have also been mapped in detail, showing that the amygdaloid complex has extensive connections with cortical and subcortical regions. analysis of fear conditioning in rats has suggested that long-term synaptic plasticity of inputs to the amygdala underlies the acquisition and perhaps storage of the fear memory. in agreement with this proposal, synaptic plasticity has been demonstrated at synapses in the amygdala in both in vitro and in vivo studies. in this review, we examine the anatomical and physiological substrates proposed to underlie amygdala function.”
Banks, S. J., Eddy, K. T., Angstadt, M., Nathan, P. J., & Luan Phan, K.. (2007). Amygdala-frontal connectivity during emotion regulation. Social Cognitive and Affective Neuroscience

Plain numerical DOI: 10.1093/scan/nsm029
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“Successful control of affect partly depends on the capacity to modulate negative emotional responses through the use of cognitive strategies (i.e., reappraisal). recent studies suggest the involvement of frontal cortical regions in the modulation of amygdala reactivity and the mediation of effective emotion regulation. however, within-subject inter-regional connectivity between amygdala and prefrontal cortex in the context of affect regulation is unknown. here, using psychophysiological interaction analyses of functional magnetic resonance imaging data, we show that activity in specific areas of the frontal cortex (dorsolateral, dorsal medial, anterior cingulate, orbital) covaries with amygdala activity and that this functional connectivity is dependent on the reappraisal task. moreover, strength of amygdala coupling with orbitofrontal cortex and dorsal medial prefrontal cortex predicts the extent of attenuation of negative affect following reappraisal. these findings highlight the importance of functional connectivity within limbic-frontal circuitry during emotion regulation.”
Urry, H. L.. (2006). Amygdala and Ventromedial Prefrontal Cortex Are Inversely Coupled during Regulation of Negative Affect and Predict the Diurnal Pattern of Cortisol Secretion among Older Adults. Journal of Neuroscience

Plain numerical DOI: 10.1523/JNEUROSCI.3215-05.2006
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“Among younger adults, the ability to willfully regulate negative affect, enabling effective responses to stressful experiences, engages regions of prefrontal cortex (pfc) and the amygdala. because regions of pfc and the amygdala are known to influence the hypothalamic-pituitary-adrenal axis, here we test whether pfc and amygdala responses during emotion regulation predict the diurnal pattern of salivary cortisol secretion. we also test whether pfc and amygdala regions are engaged during emotion regulation in older (62-to 64-year-old) rather than younger individuals. we measured brain activity using functional magnetic resonance imaging as participants regulated (increased or decreased) their affective responses or attended to negative picture stimuli. we also collected saliva samples for 1 week at home for cortisol assay. consistent with previous work in younger samples, increasing negative affect resulted in ventral lateral, dorsolateral, and dorsomedial regions of pfc and amygdala activation. in contrast to previous work, decreasing negative affect did not produce the predicted robust pattern of higher pfc and lower amygdala activation. individuals demonstrating the predicted effect (decrease ? attend in the amygdala), however, exhibited higher signal in ventromedial prefrontal cortex (vmpfc) for the same contrast. furthermore, participants displaying higher vmpfc and lower amygdala signal when decreasing compared with the attention control condition evidenced steeper, more normative declines in cortisol over the course of the day. individual differences yielded the predicted link between brain function while reducing negative affect in the laboratory and diurnal regulation of endocrine activity in the home environment.”

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