Neural and hormonal mechanisms in aggression, including the roles of the limbic system, serotonin and testosterone.

Aggression can be explained by exploring biological processes such as brain structure and biochemistry.

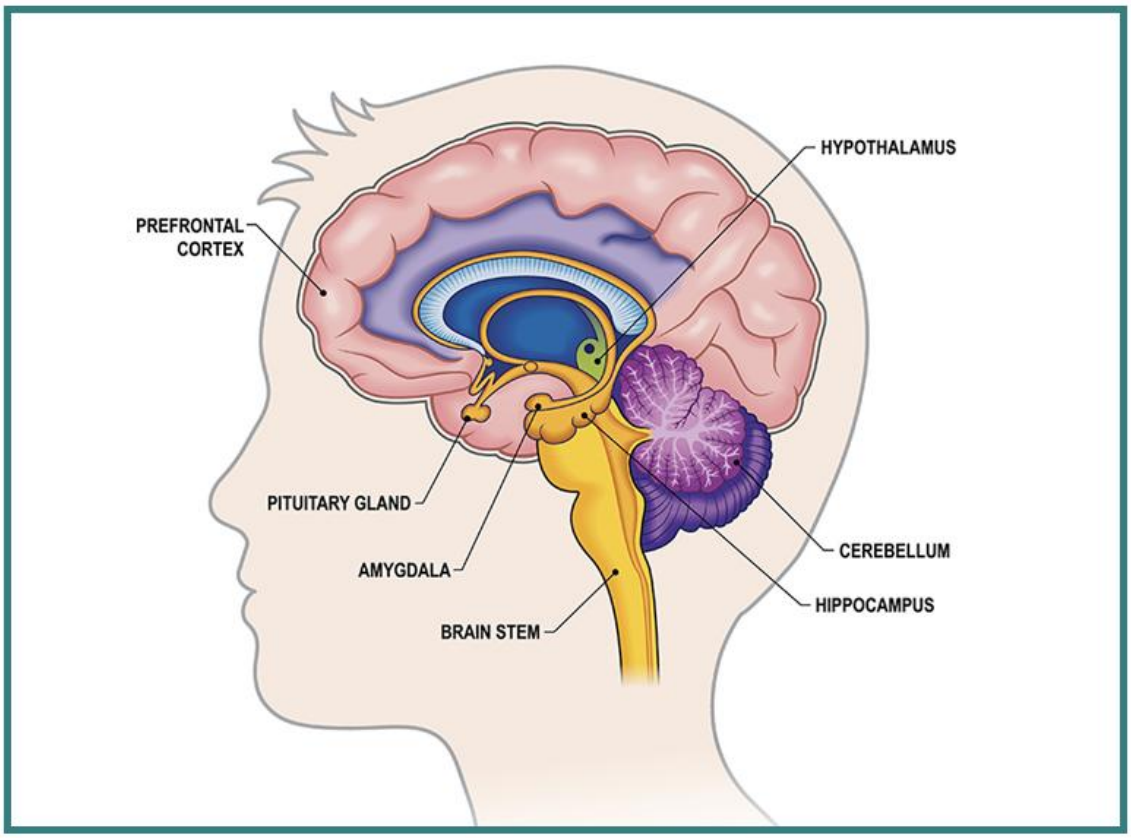
Neural Mechanisms in Aggression; the Limbic System

One explanation looks at the physical, anatomical structures in the brain implicated in aggressive behaviour. One area of the brain is the limbic system which includes the subcortical structures such as the hypothalamus, amygdala and the hippocampus. These structures are closely involved in regulating emotional behaviour including aggression.

Papez and Maclean (1952) linked the limbic system to emotional behaviours including aggression.

The limbic system plays a key role in how an organism responds to environmental threats and challenges and is therefore believed to be the key factor in whether we respond aggressively or not to an external stimulus.

One important component is the amygdala, which evaluates the emotional importance of sensory data, where overstimulation or electrical triggering can provoke sudden rage, leading to aggressive behaviour. Damage to the amygdala is linked to poor emotional expression and a lack of empathy (Raine et al, 1997).



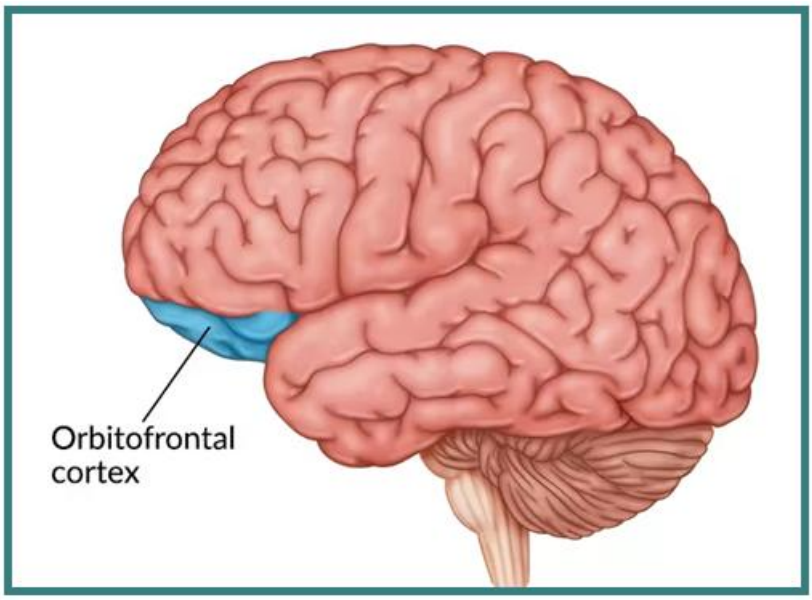
The reactivity of the amygdala in humans is an important predictor of aggressive behaviour, for example, the more responsive the amygdala, the more aggressive a person is. This has been shown in brain scan studies such as Gospic et al (2011), who subjected participants to mild provocation. They found that when participants reacted aggressively, there was a fast and heightened response by the amygdala seen on the fMRI scan .

The hypothalamus controls the autonomic nervous system and triggers physical responses like increased heart rate or defensive rage via the pituitary gland and hormones. These are activated when threats are perceived, and the sympathetic nervous system is activated as in the fight or flight response.

The hippocampus compares current threats with past experiences to help contextualise whether an aggressive response is warranted.

Neural Mechanisms in Aggression; the Orbitofrontal Cortex

The orbitofrontal cortex (OFC) acts as a crucial emotional brake in the brain. It helps control impulses, judge social situations, and stop aggressive outbursts. When the OFC is damaged, underdeveloped, or disconnected from deep brain structures like the amygdala, people often show a sharp rise in reactive and impulsive aggression.



Coccaro et al (2007) suggest that orbitalfrontal cortex activity is reduced in psychiatric disorders which feature aggression. This reduced activity disrupts the OFC's impulse control function, which in turn causes aggressive behaviour.

When the OFC has reduced activity or volume, it fails to suppress emotional outbursts triggered by lower brain structures. People prone to sudden aggressive episodes often show weak connectivity between the OFC and the amygdala.

Damage to the frontal lobe from accidents or severe stress can short-circuit this pathway, leading to sharp increases in reactive aggression, as documented in the case of Phineas Gage (Harlow, 1848).

Neural Mechanisms in Aggression; Serotonin

Serotonin is a neurotransmitter that has a widespread inhibitory effect in the brain, this means it slows down and calms neuronal activity. It acts as a mood stabiliser.

Low levels of serotonin in the brain are linked to higher rates of impulsive aggression and poor emotional control. Serotonin acts as a chemical brake in the brain, helping the frontal lobes calm the emotional and reactive signals sent by the amygdala.

Adequate serotonin supports healthy signals between the prefrontal cortex and lower emotional centres. Without this, threats or frustrations trigger an aggressive response more easily.

One strength of the serotonin explanation is research into the effect of drugs. Drugs that increase serotonin have been found to also reduce the levels of aggressive behaviour. Berman et al (2009) gave participants either a placebo or a dose of paroxetine, which is an antidepressant/ SSRI. Participants then took part in a lab-based game that involved giving and receiving electric shocks in response to provocation. The paroxetine group consistently gave fewer and less intense shocks than the placebo group. This supports the link between serotonin and aggression.

Normal levels of serotonin in the orbitalfrontal cortex are linked with reduced firing of neurons, which in turn is associated with greater behavioural self-control. Virkkunen et al (1994) compared levels of a serotonin breakdown product (5-HIAA) in the cerebrospinal fluid of violent impulsive and violent non-impulsive criminals. They found levels were significantly lower in the impulsive offenders.

Hormonal Mechanisms in Aggression; Testosterone

Testosterone is an androgen responsible for the development of masculine features. It is widely known as the male sex hormone and is thought to be linked to aggressive behaviour. Testosterone also has a role in regulating social behaviour via its influence on certain areas of the brain, particularly those implicated in aggression. Animal studies have shown that by removing the testes (source of testosterone), aggressive behaviour is significantly reduced in the males of many species, and giving injections of testosterone restores aggressive behaviour (Giammanco et al, 2005).

Dolan et al (2001) found a positive correlation between testosterone levels and aggressive behaviours in a sample of 60 male offenders, in maximum security hospitals in the UK. Most of these men had personality disorders (such as psychopathy) and histories of impulsively violent behaviour.

Archer (1991) analysed five studies involving 230 males and found a low positive correlation between testosterone and aggression, again supporting the link.

One limitation of the hormone hypothesis is there is mixed evidence for the link between testosterone and aggression in humans.

Carré and Mehta (2011) developed a dual hormone hypothesis to explain why. They claim that high levels of testosterone lead to aggressive behaviour but only when levels of cortisol are low. When cortisol is high, testosterone's influence on aggression is blocked.

Cortisol is a hormone central to the body's response to chronic stress. Therefore the combined activity of testosterone and cortisol maybe a better predictor of aggression than either hormone alone.

Unlike the common assumption that high stress causes high anger, low cortisol levels are frequently linked to chronic, persistent, and early-onset aggressive behaviour. Rather than acting alone, cortisol interacts closely with other hormones like testosterone to shape how humans respond to threats, fear, and social provocation.