IMMUNOREGULATION

2025. Vol 8

Review Paper

The Patriot's Brain: Neuroendocrine Mechanisms of National Attachment–insights From Iran

Mohammad-Reza Vaez-Mahdavi[1, 2], **Hossein Hassanpour**[1, 2*], **Leila Nasiri**[1], **Reyhane Najmi-Afshord**[1, 3]

1. Health Equity Research Center, Shahed University, Tehran, Iran.
2. Department of Basic Sciences, Faculty of Veterinary Medicine, Shahrekord University, Shahrekord, Iran.
3. Department of Physiology, Faculty of Medicine, Shahed University, Tehran, Iran.

Use your device to scan and read the article online

Citation Vaez-Mahdavi MR, Hassanpour H, Nasiri L, Najmi-Afshord R. The Patriot's Brain: Neuroendocrine Mechanisms of National Attachment–insights From Iran. Immunoregulation. 2025; 8:E27. http://dx.doi.org/10.32598/Immunoregulation.8.27

http://dx.doi.org/10.32598/Immunoregulation.8.27

Article info:
Received: 10 Jul 2025
Accepted: 28 Nov 2025
Available Online: 10 Dec 2025

Keywords:
Patriotism,
Neuroendocrinology,
Evolutionary biology,
Gene-culture coevolution

ABSTRACT

Background: Patriotism is conventionally viewed as a cultural and political phenomenon, a learned narrative of shared ancestry, collective destiny, and conscious loyalty to one's homeland. It is taught in schools, sung in anthems, and mourned in memorials. However, beneath this veneer of deliberate choice lies a more profound question: What if patriotism is not primarily an ideology but a biological drive? This review challenges the purely cultural assumption by presenting evidence for patriotism as an evolved biological phenomenon rooted in ancient neuroendocrine mechanisms that predate the nation-state, including kin selection, territoriality, and ingroup bonding.

Materials and Methods: This review synthesizes evidence from evolutionary biology, behavioral endocrinology, social neuroscience, and behavioral genetics, examining the neurochemical machinery, brain circuits, and candidate genes underlying group allegiance.

Results: Kin selection, reciprocal altruism, and territoriality provide the evolutionary scaffold for patriotism. Oxytocin drives parochial altruism; vasopressin mediates territorial defense; dopamine rewards patriotic participation; endorphins facilitate ritual bonding; serotonin enforces conformity; norepinephrine consolidates national memories; and estrogens promote affiliative bonding. However, biology provides only capacity and motivation; culture supplies content. The Iranian case illustrates how universal biological systems become uniquely conditioned by specific geopolitical threats, family-centered values, and collective rituals.

Conclusion: Patriotism is an evolved biological phenomenon, not merely a cultural construct. Neuroendocrine systems motivate culturally acquired commitments. Causal evidence exists, but causation is permissive and amplifying rather than deterministic. Culture provides universal capacity; it supplies specific content, such as flags, land, and meanings shaped by history and upbringing.

*** Corresponding Author:**
Hossein Hassanpour, PhD.
Address: *Health Equity Research Center, Shahed University, Tehran, Iran*
Phone: *+98 (912) 5434989*
E-mail: *hassanpourh@yahoo.com*

Introduction

Patriotism is often regarded as the noblest human sentiment, a conscious, deliberate, and deeply moral attachment to one's homeland [1]. We teach it in schools, sing it in anthems, and mourn those who die for it. From the Roman concept of pietas to the modern civic ritual of pledging allegiance to a flag, patriotism has traditionally been framed as a product of history, culture, and political philosophy [2]. It is observed as a learned narrative: A story we tell ourselves about shared ancestry, common sacrifice, and a collective destiny. Consequently, when we speak of a patriot, we typically conjure an image of a reflective citizen, someone who has weighed the virtues of their nation and chosen loyalty [3].

However, beneath this veneer of conscious choice and cultural indoctrination lies a more unsettling, and arguably more profound, question: What if patriotism is not primarily a political ideology, but a biological drive? What if the magnetic pull toward one's own people, territory, and symbols is not merely a social construct [4], but an evolved, genetically influenced, and neurochemically mediated adaptation, one that predates the nation-state by millions of years?

This study will lay the groundwork for exploring this radical thesis. The central argument of this review is that patriotism, far from being a purely cultural epiphenomenon, has deep biological roots. It emerges from the same evolutionary machinery that produced kin selection, territorial behavior, and ingroup bias in our non-human ancestors. To understand patriotism fully- its ferocious energy, its irrational sacrifices, and its terrifying capacity for both altruism and xenophobia, we must first understand the genes, hormones, and neural circuits that orchestrate social allegiance. This study will proceed in four parts: first, by distinguishing patriotism from nationalism through a biological lens; second, by tracing the evolutionary antecedents of group loyalty in the animal kingdom; third, by examining the genetic and neuroendocrine mechanisms that underpin human tribalism; and finally, by addressing the ethical and philosophical implications of a biological account of patriotism.

Redefining the terrain: Patriotism vs nationalism

Before delving into biology, we must clarify our subject. Political theory traditionally distinguishes between patriotism (affection for one's homeland, its institutions, and its people) and nationalism (the belief in the superiority of one's nation and the right to dominate others). The former is often seen as benign, the latter as toxic. However, from a biological perspective, this distinction is less categorical than continuous. Both phenomena arise from the same underlying suite of evolved biases: Preference for familiar faces, defense of resources, and the release of oxytocin upon seeing ingroup symbols [5]. The patriot who flies a flag on a holiday and the nationalist who marches for ethnic purity are drawing on the same ancient neural toolkit; they differ only in the intensity of activation and the cultural narratives that interpret the impulse [6].

Thus, in this research, we will use "patriotism" in a broad, ethological sense: The evolved tendency to form preferential bonds with a defined human group and its geographical territory, coupled with a willingness to defend that group and territory against perceived threats. This definition does not require conscious reflection. It can manifest as the euphoria of a sports fan seeing their country win a gold medal, the grief of a diaspora member yearning for their ancestral soil, or the reflexive aggression of a border patrol agent. The biological patriot is not the philosopher-king of civic virtue; it is the mammal that recognizes "us" and "ours."

Deep Time: Evolutionary antecedents of group loyalty

To view patriotism as biological, we must first step off the short stage of recorded history, a mere 5,000 years, and into the abyss of deep evolutionary time, spanning tens of millions of years. The behavioral ingredients of patriotism are far older than any nation, any city-state, or even any human language [7].

Consider first kin selection, the theory that revolutionized mid-20th-century biology. An organism can propagate its genes not only by reproducing directly but also by aiding relatives who share copies of those genes. This logic predicts altruism toward kin; however, it also provides a scaffold for group loyalty [8]. Early humans lived in small bands of closely related individuals. Affection for one's band was, in effect, affection for one's extended family. As groups grew larger and began to include non-kin, the brain's kinship-detection mechanisms were co-opted [9]. We began to treat fellow tribe members as "fictive kin." The same neural circuits that make a mother protect her child make a soldier protect his platoon and, by extension, his nation [10].

Second, reciprocal altruism and indirect reciprocity (reputation-based cooperation) further bound groups together. In a world without police or contracts, an indi-

vidual who defected from the group risked ostracism and death [11]. Conversely, those who displayed conspicuous loyalty and sacrificed for the collective gained status, mates, and protection. Patriotism, from this vantage, is an honest signal of cooperative intent. The willingness to die for the flag is the ultimate costly signal, proving beyond doubt that one can be trusted. Evolution thus selected for brains that experience genuine emotional rewards when conforming to group norms and punishing traitors [12].

Third, and most viscerally, territoriality. From wolves to chimpanzees to pre-agricultural humans, most social mammals defend a home range. Territorial defense is not a metaphor for patriotism; it is its literal precursor. When a male chimpanzee patrols the border of his community's territory and kills a neighboring male, he is engaging in proto-patriotic behavior. He does not fight for an abstract concept of "nation," but for access to food, safety for his kin, and the genetic legacy of his group [13]. The human patriot who declares, "this land is our land," is channeling that same limbic imperative, now draped in the symbolic clothing of maps and borders [14].

Figure 1 provides a schematic overview of the multilayered factors contributing to patriotism. The framework integrates distal evolutionary drivers (kin selection, territoriality, reciprocal altruism) with proximal neuroendocrine mechanisms (oxytocin, vasopressin, dopamine, etc.) and modulating socio-ecological variables (threat environment, collective rituals, family-centered values). This model illustrates that patriotism is neither purely biological nor purely cultural but emerges from dynamic interactions across these levels.

Thus, the evolutionary scaffold for patriotism includes: (a) preferential altruism toward genetically related or familiar individuals, (b) a psychological reward system for group conformity and sacrifice, and (c) a defensive aggression triggered by territorial intrusion. None of these requires a history textbook.

Neuroendocrine machinery: Oxytocin, testosterone, and the patriot's brain

If patriotism is indeed a biological phenomenon, it must leave measurable traces in the chemistry and architecture of the human body. It cannot remain an abstract feeling or a disembodied idea. Over the past two decades, social neuroscience, endocrinology, and neuroimaging have begun to map these traces precisely. What they reveal is that the patriot's fervor, the lump in the throat at the sound of an anthem, and the reflexive defensiveness when the flag is burned are not merely cultural reflexes. They are orchestrated by a complex symphony of hormones, neuropeptides, and monoamines, acting upon a densely interconnected set of brain structures that evolved long before the first nation-state was ever conceived [15].

While earlier studies often focused narrowly on oxytocin and testosterone [16, 17], a comprehensive biological account must expand the cast of characters considerably. The neuroendocrine machinery of patriotism includes: oxytocin (parochial bonding) [18], arginine vasopressin (AVP) (territorial aggression and pair-bonding) [19], testosterone (dominance and status defense) [20], cortisol (threat vigilance) [21], dopamine (reward and reinforcement) [22], serotonin (social conformity and punishment sensitivity) [23], endorphins (ritual bonding and pain tolerance) [24], norepinephrine (NE) (arousal and memory consolidation) [25], and estrogens (affiliative bonding and ingroup preference) [26]. Each of these interacts with specific neural circuits, the amygdala (threat detection) [27], hypothalamus (hormonal control) [28], ventral tegmental area (VTA) and nucleus accumbens (reward) [29], insula (interoceptive salience) [30], anterior cingulate cortex (ACC) (conflict and pain monitoring) [31], orbitofrontal cortex (OFC) (value assignment to symbols) [32], temporoparietal junction (self-other distinction) [33], and the default mode network (self-referential thought) [34].

Oxytocin: The architect of parochial altruism

Oxytocin is a nine-amino-acid neuropeptide synthesized primarily in the paraventricular nucleus (PVN) and supraoptic nucleus of the hypothalamus, from which it is released both into the bloodstream (via the posterior pituitary) and into the brain itself via long-range axonal projections. Far from being a simple "love hormone," oxytocin acts as a social salience molecule; it amplifies the emotional significance of social stimuli, but the valence (positive or negative) depends entirely on context and prior learning [35].

The relevance of patriotism was established in a landmark series of experiments using the intergroup prisoner's dilemma and taxation games. Intranasal oxytocin administration reliably increased ingroup trust, cooperation, and willingness to sacrifice personal resources for the benefit of one's own group, even when groups were formed arbitrarily (e.g. based on preference for a particular painter) [36]. Crucially, oxytocin simultaneously increased defensive aggression against out-group members when the out-group was perceived as threat-

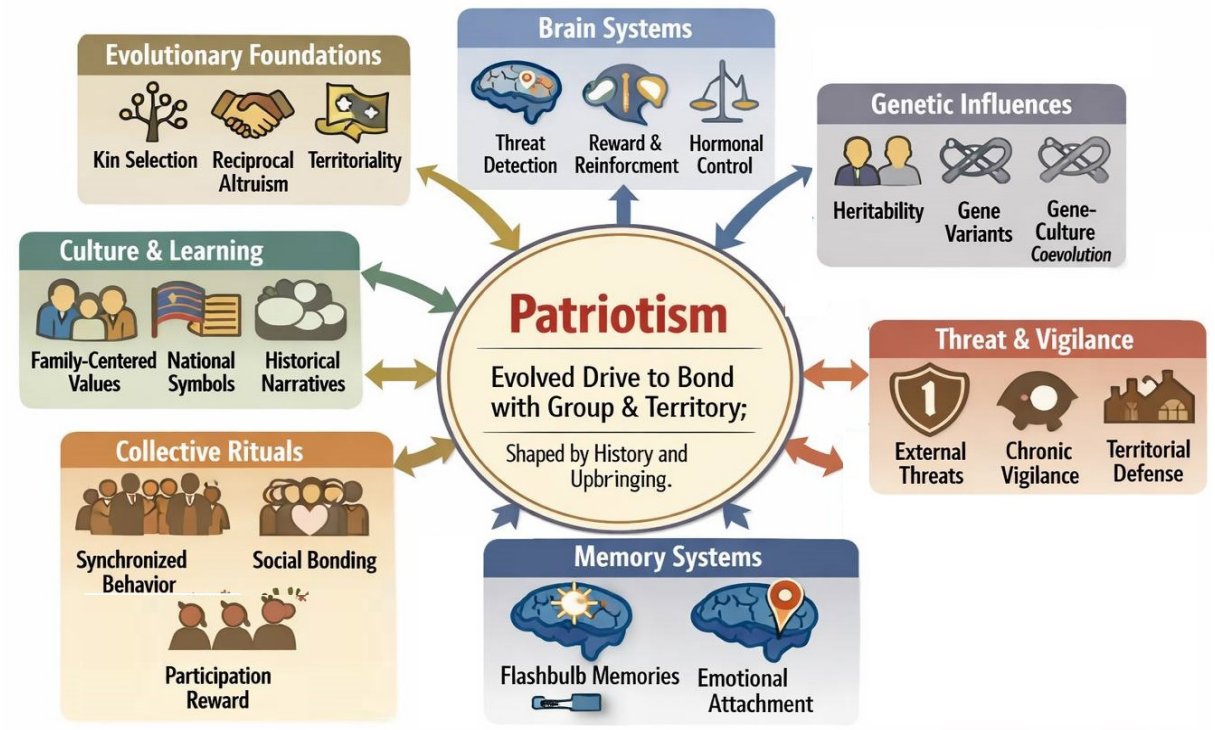

Figure 1. Schematic illustration of several factors influencing patriotism, created with the assistance of microsoft copilot AI

ening. This pattern, termed parochial altruism, is the neurochemical signature of patriotic sacrifice: love for one's own, coupled with indifference or hostility toward outsiders [37].

The neural mechanism involves oxytocin binding to oxytocin receptors (OXTRs) that are densely distributed in the amygdala, nucleus accumbens, ACC, and insula. In the amygdala, oxytocin reduces fear responses to ingroup faces but not to out-group faces, effectively creating a neural safety signal for "us" and leaving "them" in a state of default threat [38]. In the nucleus accumbens, oxytocin enhances reward responses to ingroup praise and cooperation, reinforcing future patriotic behavior. This is why a standing ovation at a national celebration feels euphoric: Oxytocin potentiates dopamine release in the reward circuitry [39].

Moreover, genetic variation in the OXTR gene predicts individual differences in patriotism. The G allele (associated with greater receptor expression and/or function) is linked to higher levels of national attachment, ingroup trust, and even physiological reactivity (skin conductance) to national symbols. In this sense, patriotism is partially heritable via the molecular machinery that binds us to our group [40].

Genetic OXTR findings are correlational, but experimental administration studies provide causal evidence. It has been shown that intranasal oxytocin causes an increase in ingroup trust and out-group aggression [41]. It was also confirmed that oxytocin causes a causal enhancement of coordinated out-group attacks. However, these are acute laboratory effects; whether chronic oxytocin causes lifelong patriotism remains unproven. The convergence of genetic and experimental evidence supports a permissive, not deterministic, causal role.

AVP: Territorial molecule

Often overshadowed by oxytocin, AVP is arguably even more critical for understanding the territorial and defensive components of patriotism. Structurally similar to oxytocin (differing by just two amino acids), vasopressin is synthesized in the same hypothalamic nuclei and acts via three receptor subtypes: V1a (in brain), V1b (pituitary), and V2 (kidney) [42]. For patriotism, the V1a receptor is paramount [43].

In voles, a classic model system for social bonding, species differences in territoriality and pair-bonding map directly onto V1a receptor density in the ventral pallidum and lateral septum [44]. Highly territorial prairie voles show dense V1a binding in these regions, while non-territorial montane voles do not. When humans

view images of their national territory, maps, borderlands, and sacred sites, vasopressin is released, and functional imaging reveals activation of the V1a-rich ventral pallidum. This suggests that the defense of geographical borders is not a mere political abstraction but an ancient, neuropeptide-driven instinct. The patriot who says "this land is our land" is, neurochemically, a territorial vole writ large [45].

Furthermore, vasopressin modulates intermale aggression, a key component of patriotic defense [46]. In humans, genetic variants of the AVP receptor 1A (AVPR1a) gene (particularly the RS3 promoter repeat) are associated with heightened trait aggression and, in some studies, increased endorsement of defensive militarism and border enforcement [47]. The burning of a flag may not merely offend cultural sensibilities; it may trigger a vasopressin-mediated threat response that feels viscerally like a physical invasion of personal space.

While most human studies are correlational, animal models provide causal evidence. In prairie voles, site-specific manipulation of V1a receptor density in the ventral pallidum causes changes in territorial aggression [48]. In humans, the absence of direct vasopressin administration studies limits causal inference. However, genetic association studies (AVPR1a polymorphisms) suggest that individual differences in vasopressin signaling contribute to variations in defensive territorial attitudes [49].

Testosterone, cortisol, and HPA axis: Vigilance and dominance

Testosterone is a steroid hormone produced in the Leydig cells of the testes (and, in smaller amounts, in the adrenal cortex and ovaries). Its effects on patriotism are best understood through the dual-hormone hypothesis, which posits that testosterone promotes status-seeking and dominance behaviors, but only when cortisol (the stress hormone) is low. When cortisol is high, indicating chronic threat testosterone's effects are suppressed or redirected [50].

Patriotic contexts reliably elevate testosterone [16]. In a study, fans of a winning soccer team showed sustained testosterone increases after a match, while fans of the losing team showed declines [51]. Researchers have measured testosterone in baseline, anticipation, and competition phases of international sporting events. The largest surges occur before matches against historic rivals, out-groups with a long history of symbolic threat. This is not merely competition arousal; it is specifically patriotic, because the self is fused with the national team. The fan's brain treats the team's victory as a personal status gain, mediated by testosterone acting on androgen receptors in the medial preoptic area and ventromedial hypothalamus regions that control social aggression and dominance displays [52].

Cortisol, secreted from the adrenal cortex under control of the hypothalamic-pituitary-adrenal (HPA) axis, tells a different story. When a nation experiences a genuine threat, terrorist attack, war declaration, or economic sanctions, cortisol levels rise sharply, mobilizing glucose and preparing the body for fight-or-flight [53]. However, chronic patriotic vigilance (e.g. living under a constant perceived threat from a neighboring country) leads to HPA axis dysregulation: flattened diurnal cortisol slopes, reduced feedback sensitivity, and eventually burnout. This is the biology of the perpetual patriot, the individual for whom the national flag is never lowered, because the threat is never gone [54].

Studies of testosterone administration in humans provide causal evidence. It has been indicated that exogenous testosterone administration causes increased approach behavior toward dominant others and heightened status-seeking [55]. In sports contexts, the anticipatory rise in testosterone before matches demonstrates temporal precedence: The hormone change precedes, not follows, the patriotic event [56]. This temporal pattern suggests a preparatory causal role rather than a reactive consequence. For cortisol, causal evidence is weaker; while threat perception clearly elevates cortisol [57], whether cortisol itself causes patriotic vigilance or merely reflects it remains unresolved.

Dopamine and reward circuitry: Why patriotism feels good

Patriotism feels good because it reliably activates the brain's mesolimbic reward circuitry, the same dopaminergic network that mediates pleasure, motivation, and reinforcement learning for natural rewards. When individuals engage in patriotic rituals, sing national anthems, or experience collective national pride, the VTA releases dopamine that projects to limbic targets such as the nucleus accumbens, amygdala, and prefrontal cortex, generating a subjective sense of reward and reinforcing group-affiliative behavior [58]. This neurochemical response is amplified by the social dimension of patriotism. Oxytocin, a neuropeptide central to social bonding, interacts with dopaminergic pathways to enhance the salience of in-group identity and prosocial outcomes [59]. Moreover, the amygdala and hippocampus encode the

emotional and declarative memories associated with national symbols, while the OFC evaluates their incentive value, creating a learned association between national identity and positive affect that sustains motivated engagement with patriotic behaviors over time [60].

While direct dopamine administration studies are rare in humans, pharmacological blockade studies provide causal evidence. Dopamine antagonists reduce reward responses to social praise and cooperation, impairing the reinforcement learning that sustains patriotic behavior [61]. Animal models show that optogenetic manipulation of dopamine neurons in the VTA causally alters social approach and avoidance behaviors [62]. The causal role of dopamine in patriotic reward is therefore well-supported, even if studies specifically targeting patriotism are limited.

Serotonin: Fairness, hierarchy, and the social brain of patriotism

Serotonin (5-hydroxytryptamine, 5-HT) is a monoamine neurotransmitter synthesized from tryptophan, with cell bodies in the raphe nuclei of the brainstem projecting widely to the forebrain [63]. While dopamine drives the hedonic "high" of patriotic reward, serotonin (5-HT) provides the neurochemical foundation that makes sustained patriotism feel stable, meaningful, and socially coherent. Serotonin is heavily concentrated in limbic structures including the cingulate cortex, insula, OFC, and ventral striatum that collectively constitute the "social brain"[64]. In this circuitry, serotonin does not simply produce pleasure; it modulates the valuation of social outcomes, enhances self-relevance processing, and promotes adaptive conformity to group norms, all of which are essential for the experience of patriotic belonging. Pharmacological evidence demonstrates that serotonin shapes how individuals evaluate fairness and reciprocity within groups. Serotonin depletion blunts neural responses to fair social exchanges in the ventral striatum and medial prefrontal cortex, while serotonin enhancement amplifies positive social preferences and cooperative behavior [65]. This mechanism is directly relevant to patriotism: when citizens perceive their nation as treating them fairly or when they contribute to collective welfare, serotonergic signaling assigns positive subjective value to these experiences, reinforcing continued identification with the national group. Moreover, serotonin facilitates social adaptation by modulating how the medial prefrontal cortex integrates self-relevance with social feedback, enabling individuals to align their behavior with prevailing national norms and values [23].

The serotonergic system also underlies the hierarchical and affiliative dimensions of group life that patriotism entails. Research on social hierarchies indicates that dominance and affiliation, two core axes of group dynamics, are both regulated by serotonin and may be co-represented in the hippocampus as a two-dimensional social map [66]. In the context of patriotism, this means serotonin helps individuals navigate their position within the national collective: It calms the anxiety of subordination, enhances the satisfaction of belonging, and promotes prosocial deference to national symbols and leaders. Notably, serotonergic psychedelics that activate 5-HT2A receptors reduce the psychological boundary between the self and others, producing feelings of "oneness" that mirror the transcendent sense of unity experienced during patriotic rituals [23]. Neuroanatomical studies further distinguish the neural substrates of patriotism from nationalism, highlighting serotonin's role in well-being-oriented group attachment. Higher patriotism correlates with structural variation in the rostrolateral prefrontal cortex, an area associated with quality of life and positive affect. In contrast, nationalism maps onto regions linked to social comparison and aggression [67]. This suggests that the serotonin-mediated sense of contentment and social harmony characteristic of patriotism is neurobiologically distinct from the dominance-driven, often hostile, in-group bias of nationalism.

Tryptophan depletion studies provide the strongest causal evidence linking serotonin to social behavior. Depleting serotonin precursor causally reduces neural responses to fair social exchanges and impairs cooperative behavior [68]. Serotonin-enhancing drugs causally increase prosocial behavior and reduce aggression toward out-groups [69]. This establishes that serotonin tone causes changes in social conformity and in-group preference, not merely correlates with them. The causal pathway from serotonin to patriotic attachment is thus indirect but well-supported: Serotonin facilitates the social cohesion and norm-following that patriotism requires.

NE: Arousal, memory, and the vividness of patriotic moments

NE provides the neurochemical substrate that makes patriotism salient, urgent, and action-oriented. Synthesized from dopamine in the locus coeruleus (LC) and distributed throughout the cortex and limbic system, the LC-NE system governs arousal, attention, and stress responsivity, functions that are indispensable when national identity becomes emotionally charged [70]. In the context of patriotism, NE does not merely heighten alertness; it amplifies the perceived significance of national symbols,

threats to the in-group, and opportunities for collective action, effectively tagging patriotic stimuli as worthy of immediate cognitive and behavioral resources [71].

The LC-NE system operates in two modes that map directly onto the dynamics of patriotic engagement. In its tonic mode, characterized by slow, sustained discharge, NE maintains a baseline level of vigilance and arousal that keeps individuals attuned to the national environment, monitoring news, social cues, and symbolic events that bear on group identity [70]. In its phasic mode, triggered by novel or salient stimuli at high-frequency bursts, NE creates sharp spikes in release that orient attention toward unexpected threats or opportunities for the nation, such as geopolitical crises, national tragedies, or moments of collective triumph [72]. This phasic response explains why patriotic sentiment often surges dramatically during crises: The LC-NE system flags these events as highly significant, mobilizing emotional and cognitive resources for in-group defense or celebration.

Critically, NE shapes how individuals process social and moral information in intergroup contexts. Pharmacological blockade of β-adrenergic receptors with propranolol, a drug that crosses the blood-brain barrier and attenuates central noradrenergic signaling, has been shown to reduce implicit racial bias and alter neural responses to out-group faces, specifically diminishing activity in the thalamus and fusiform gyrus regions involved in the initial perception and evaluation of emotional social stimuli [73]. This suggests that NE-mediated arousal is not merely a background state but actively modulates the salience of in-group versus out-group distinctions, effectively sharpening the boundary between "us" and "them" that patriotism relies upon. Moreover, NE interacts with oxytocin in the hypothalamic PVN and amygdala, where noradrenergic activation can indirectly promote oxytocin release, thereby coupling emotional arousal with social bonding mechanisms that reinforce in-group favoritism [74].

Pharmacological blockade of β-adrenergic receptors with propranolol causally reduces implicit racial bias and alters neural responses to out-group faces [75]. This demonstrates that noradrenergic signaling actively causes the salience of in-group/out-group distinctions. The LC-NE system's role in memory consolidation is also causal: noradrenergic blockade impairs the formation of emotionally charged national memories [76]. These findings establish NE as a causal contributor to the arousal, memory, and intergroup salience that characterize patriotic experience.

Estrogens: Overlooked female axis of patriotism

Any complete neuroendocrine account must include estrogens (estradiol, estrone, and estriol), which are not merely "female" hormones but are present and active in both sexes (though at different levels). Estrogen receptors (ER-α and ER-β) are densely distributed in the amygdala, hypothalamus, hippocampus, and prefrontal cortex [77]. Estrogens modulate oxytocin release, enhance social memory, and promote affiliative bonding [78].

In patriotism, estradiol administration increases in-group trust and cooperation in women, and reduces out-group derogation, suggesting that the female hormonal profile may favor a more affiliative, less aggressive form of patriotism [79]. This is consistent with evolutionary theories of female coalitional psychology, in which, women's survival often depended more on within-group alliances than on intergroup aggression. Estrogen-mediated patriotism may manifest as volunteerism, national charity, and the emotional bond to the "homeland as mother", a common personification across cultures.

Studies on estradiol administration in women demonstrate causal effects on in-group trust and cooperation [80]. In animal models, estrogen receptor knockout causally abolishes female social bonding behaviors [81]. Human causal evidence is limited, but existing pharmacological studies suggest that estrogens actively modulate affiliative responses to in-group members. The causal case for estrogens in patriotism remains moderate: suggestive but requiring further human experimental studies. Figure 2 shows the hypothesized neuroendocrine mechanisms underlying patriotic responses.

Integration: A dynamic neuroendocrine network

No single hormone or brain region acts independently. The patriot's brain is a dynamic, state-dependent network. This network is not fixed; it is experience-dependent and plastic [82]. A child who grows up singing the anthem at school assemblies, watching national parades, and hearing stories of patriotic sacrifice will develop strengthened synaptic connections between the flag's visual features and the reward circuitry. The flag becomes a supernormal stimulus, an artificially amplified trigger for an evolved social-bonding mechanism. This is why a piece of cloth can make grown adults weep: the cloth is biologically irrelevant, but the neural pathways it activates are ancient and sacred [83].

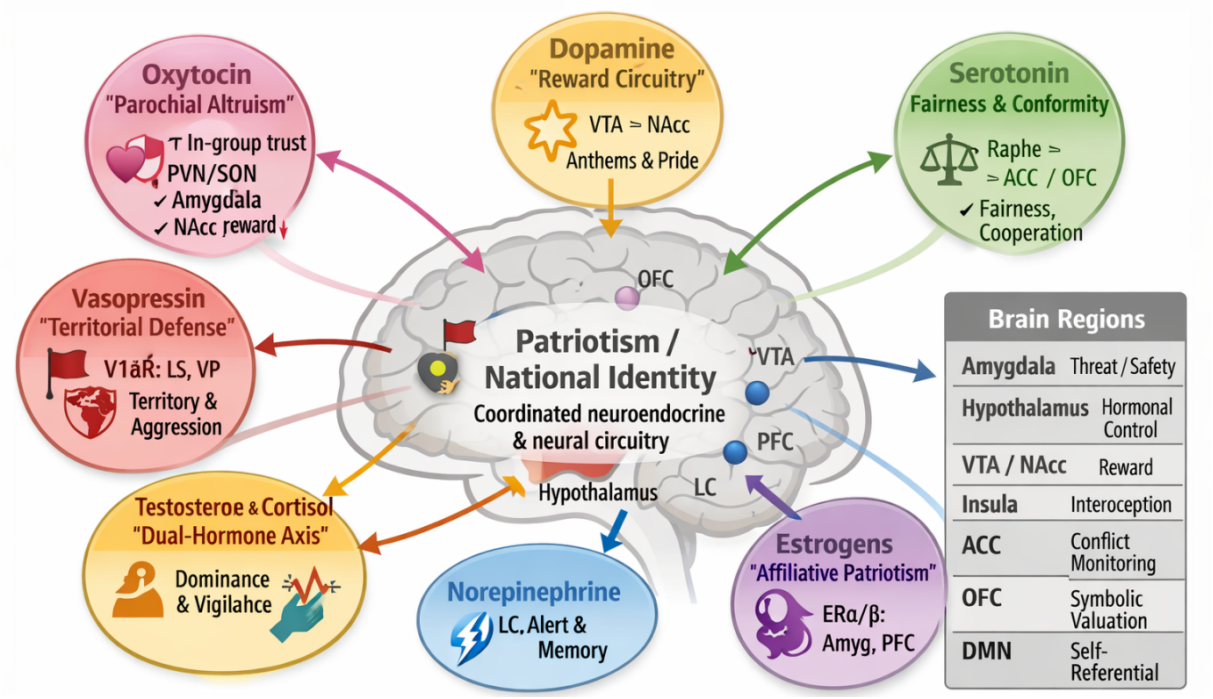

Figure 2. Schematic illustration of the neuroendocrine mechanisms hypothesized to be involved in patriotic responses

Abbreviations: PVN: Paraventricular nucleus; SON: Supraoptic nucleus; NAcc, nucleus accumbens; V1aR: Vasopressin V1a receptor; LS: Lateral septum; VP: Ventral pallidum; VTA: Ventral tegmental area; OFC: Orbitofrontal cortex; PFC: Prefrontal cortex; LC: Locus coeruleus; ACC: Anterior cingulate cortex; ERα/β: Estrogen receptor alpha/beta; Amyg: Amygdala; DMN, default mode network.

Created with the assistance of Microsoft Copilot AI.

In sum, the neuroendocrine machinery of patriotism is not a sideshow to the "real" cultural phenomenon [84]. It is the phenomenon, operating at a level of detail and causal specificity that cultural analysis alone cannot reach. To understand why patriots sacrifice, why they feel pain at national insults, why rituals bind them together, and why threats to the flag feel like threats to the self, we must understand oxytocin, vasopressin, testosterone, cortisol, dopamine, serotonin, endorphins, NE, estrogens, and the intricate brain circuits through which they act. Patriotism lives in the hypothalamus, the amygdala, the ventral striatum, and the LC. It is written in neuropeptides and steroid hormones. Moreover, it is there, in the biology, that we must look to find its deepest truth.

Genetics: Heritability of allegiance

No biological account is complete without considering heritability. Twin studies have consistently found that political orientations, including patriotic attitudes and nationalist sentiments, are moderately heritable [85]. The Minnesota Twin Family Study, for example, reported that identical twins (sharing 100% of their genes) are significantly more similar in their degree of patriotic attachment than fraternal twins (sharing 50% of their segregating genes), even when the twins were reared apart in different adoptive homes [86]. This suggests that patriotism is not purely a family-transmitted cultural value; it has a genetic component.

Twin studies do not merely show correlation; they show heritability, which implies genetic causation. Identical twins reared apart are more similar in patriotism than fraternal twins reared together, meaning genetic variation causes variation in patriotic attachment [87]. This is not to say genes 'determine' patriotism; the environment remains crucial, but genetic differences contribute causally to individual differences in patriotic susceptibility.

Candidate gene studies have pointed toward polymorphisms in the dopamine receptor D4 gene, specifically the 7-repeat allele associated with novelty-seeking and sensitivity to social rewards, as well as variants in the setion and negative emotionality. Individuals with certain alleles may be more prone to experience intense group attachment or to perceive out-groups as dangerous [88]. These are not "genes for patriotism" in any deterministic sense; environmental context remains crucial, but

they are biological biases that shape the probability that a given cultural message (e.g. "love your country") will take root and produce fervent allegiance.

Furthermore, evolutionary genetic models of gene-culture coevolution suggest that genes and culture are not separate forces but interact dynamically. For instance, the expansion of large-scale societies in the last 10,000 years, from tribes to chiefdoms to empires to nation-states, may have exerted selective pressure on genes that facilitate cooperation with non-kin [89].

Populations that developed cultural norms of patriotic sacrifice (e.g. military conscription, taxation for public goods) may have simultaneously selected for genetic variants that make such sacrifices emotionally rewarding. In other words, patriotism is not a cultural veneer atop a biological chassis; the two have shaped each other over evolutionary time.

Critique: Culture, contingency, and limits of biology

At this point, a careful reader might object: If patriotism is biological, why do people switch national loyalties? Why do immigrants adopt new flags? Why do historical enemies become allies? These are valid challenges. The biological account does not deny the overwhelming importance of cultural learning, historical contingency, and symbolic meaning. Rather, it insists that biology provides the capacity and motivation for group allegiance, while culture provides the content [90]. The human brain is born prepared to bond with a group and defend a territory; but which group and which territory is written by upbringing, language, and shared history [91]. Thus, the biological perspective does not reduce patriotism to a simple reflex or a "selfish gene" calculation. It enriches our understanding by revealing the ancient, visceral roots of what feels like a modern, rational choice.

Iranian patriotism and biological characteristics

Based on the biological framework developed above, Iranian patriotism is not caused by any unique or exclusive 'patriotism gene.' Rather, universal biological mechanisms - oxytocin, vasopressin, cortisol, dopamine are modulated by specific historical and cultural conditions. This is a causal claim about context-dependent biological amplification: The same hormones that produce group bonding everywhere are chronically activated by Iran's specific threat environment and cultural practices. However, any complete biological account of Iranian patriotism must extend beyond territorial defense. Iranian national identity is equally defined by two other pillars: Transnational identification with the oppressed (Palestine, Lebanon, Gaza) and refusal to submit to oppression, a principle deeply rooted in Shia religious culture. These dimensions engage the same universal biological machinery but through different neuroendocrine pathways. The oxytocin system, which evolution designed for bonding with kin, can be culturally extended to include ideological and religious kin. Through the Shia narrative of Karbala, which frames Hussein's martyrdom as a universal stand against tyranny, the "ingroup" expands beyond Iran's borders to include co-religionists and the globally oppressed. When Iranians express solidarity with Gaza or Lebanon, oxytocin release in the amygdala and nucleus accumbens is triggered not by geographic proximity but by shared values and shared victimhood, a culturally conditioned expansion of the empathy circle.

"Being a defender of the oppressed" functions as a valued social role that activates the mesolimbic dopamine system. The VTA-nucleus accumbens pathway responds to identity-consistent behavior, generating rewards through: (a) self-esteem enhancement, (b) social recognition, and (c) moral identity reinforcement. This is the same circuitry that makes any patriotic behavior feel good, but here the "group" is defined by values rather than geography. Serotonergic enforcement of anti-oppression norms provides the third neurochemical pillar. The refusal to submit to oppression—rooted in the Karbala narrative—engages the serotonin system, which mediates moral norm enforcement, fairness perception, and sensitivity to punishment. Serotonin modulates the ACC and insula in detecting moral violations, making oppression not merely a political issue but a neurochemically salient moral transgression that triggers outrage, while resistance activates reward for virtue.

Consider first the dimension of threat. Iran's long history of foreign invasions, its distinct geographical borders defined by mountains and deserts, and decades of post-revolutionary geopolitical tension, including a devastating eight-year war, ongoing sanctions, and recurrent military threats, have created a context of chronic threat vigilance. Most recently, Iran's direct military confrontation with Israel and the United States, escalated since February 2026, has intensified this threat environment, sustaining elevated cortisol baselines and keeping the vasopressin-mediated territorial defense system in a state of chronic alert, thereby amplifying patriotic responses through the very neuroendocrine mechanisms described above. In biological terms, one might expect that an individual raised in such an environment would operate with a heightened baseline of cortisol, the stress

hormone, keeping the amygdala primed to detect outgroup threats. Consequently, the vasopressin-mediated territorial defense system the same neuropeptide circuit that makes a prairie vole defend its home range could become easily triggered by symbolic cues such as a map of Iran, a reference to the Persian Gulf, or a perceived insult to national borders. This is not because Iranian vasopressin receptors are different from those of any other human population, but because they have been repeatedly activated and strengthened through associative learning across generations and within individual lifetimes. Second, consider the dimension of bonding. Iranian culture is intensely family-oriented, with strong emphasis on kinship bonds, respect for elders, and collective obligation. This cultural feature directly engages the oxytocin system, which evolution designed to bond mothers to infants and relatives to one another. Through a process of generalization, the same neural circuits that produce affection for one's extended family can be extended outward to include non-kin fellow citizens, effectively transforming the entire nation into a circle of fictive kin. This may help explain why an Iranian might refer to a stranger as "brother" or "sister," and why the nation is so often personified as a mother-Mother Iran, the Motherland. Third, consider the role of collective rituals. Iran possesses a rich calendar of large-scale collective events, from the mourning processions of Ashura, where millions walk and chant in unison, to the mass rallies of 22 Bahman, to the shared festivities of Nowruz. These events are explicitly designed to synchronize human behavior. Synchronized singing, marching, and even collective weeping are known to trigger the release of beta-endorphins, the brain's natural opioids, producing a state of low-grade euphoria and increased pain tolerance. This is why participants can endure hours of walking in cold weather or crushing crowds without complaint. At the same time, such rituals engage the brain's dopamine reward circuitry, making the act of patriotic participation feel genuinely pleasurable, similar to the reward experienced from eating or social bonding. Over time, national symbols such as the flag, the anthem, and even specific poetic verses by Hafez or Ferdowsi can become conditioned reinforcers, capable of triggering dopamine release on their own. Beyond defensive threat, Iranian patriotism is also sustained by appetitive cultural pride, daily engagement with ancient civilization, authentic art (architecture, miniature painting), and especially Persian poetry (Ferdowsi, Hafez, Saadi). These cultural treasures function as supernormal stimuli that directly engage the dopaminergic reward system, making cultural identity feel intrinsically pleasurable, while simultaneously activating oxytocin-mediated bonding through shared recitation and collective appreciation, transforming the nation into fictive kin bound by millennia of shared aesthetic and literary heritage. Fourth, consider the moral dimension of betrayal. Concepts, such as "spy," "traitor," and "hypocrite", carry an unusually intense moral outrage in Iranian public discourse. The biological basis for this likely involves the serotonin system. Observing an in-group defector activates the ACC and insula regions rich in serotonin receptors, producing feelings of disgust and a desire to punish. This response is amplified by cultural narratives that elevate martyrdom to the highest virtue and treat treason as an unforgivable sin. An environment of constant perceived threat may further heighten such sensitivities, regardless of any specific genetic predisposition. Finally, consider the persistence of patriotic memory. NE consolidates emotionally arousing experiences into lasting, vivid memory. Generations of Iranians carry what might be called flashbulb memories of national events: the revolution of 1979, the long years of the Iran-Iraq war, the downing of flight 752, the assassination of Qasem Soleimani. These memories do not merely inform political opinions; they are physically encoded in the amygdala and hippocampus, emotionally charged and resistant to forgetting. A fifty-year-old Iranian weeping at a memorial for the war is not merely performing a cultural script; from a neurobiological perspective, he or she is reliving a noradrenergic event from decades past.

The causal inference here is not that Iranians are biologically different from other populations, but that their unique environment differentially engages their universal biology. The hormones do not cause Iranian patriotism in a vacuum; they amplify it in response to the specific cultural and geopolitical context. This is consistent with the broader framework: biology provides capacity and motivation; culture provides content and triggers.

Figure 3 schematically illustrates several contextual factors that may influence patriotism in general, with potential relevance to the Iranian case discussed below.

Conclusion

Patriotism is not merely a cultural or political ideology but an evolved biological phenomenon. It emerges from ancient neuroendocrine mechanisms - oxytocin, vasopressin, dopamine, endorphins, serotonin, NE, and estrogens that predate the nation-state by millions of years. These systems drive in-group bonding, territorial defense, ritual cohesion, and moral enforcement. Twin and genetic studies confirm moderate heritability, while gene-culture coevolution explains how biology provides the capacity for alle-

IMMUNOREGULATION

Figure 3. Schematic illustration of several factors influencing the patriotism, created with the assistance of Microsoft Copilot AI

giance and culture supplies the content. Crucially, however, the relationship between biology and patriotism is not one of simple causation. Hormones are neither necessary nor sufficient for patriotism. Individuals with low oxytocin can still be deeply patriotic, and administering oxytocin does not make someone patriotic toward arbitrary groups. Rather, neuroendocrine systems provide a permissive, amplifying, and motivational substrate. They lower the threshold for patriotic learning, enhance the emotional rewards of in-group affiliation, intensify defensive responses to outgroup threats, and reinforce patriotic behavior through reward and memory consolidation. Culture provides the content the flag, the anthem, the land; biology provides the motivational potency that makes these symbols feel viscerally meaningful.

The causal arrow runs both ways: culture shapes the contexts in which hormones are released (e.g., rituals, threats, celebrations), and hormones shape the intensity with which cultural commitments are felt. This is not a reductive biological determinism but a dynamic, bidirectional interaction between biology and culture.

The case of Iranian patriotism illustrates how universal biological machinery becomes uniquely conditioned by specific historical and cultural contexts. Understanding patriotism through this neuroendocrine lens does not reduce it to reflex or chemical determinism. Rather, it reveals the ancient, visceral roots beneath rational choice and shows why patriotism feels so powerfully real, even when its objects, flags, borders, and anthems are culturally constructed. Patriotism lives in the hypothalamus, the amygdala, the ventral striatum, and the LC. But it is also written in poetry, taught in schools, and sung in anthems. Biology is universal; content is shaped by history and upbringing.

Ethical Considerations

Compliance with ethical guidelines

This study was approved by the Ethics Committee of the Shahed University, Tehran, Iran.

Funding

This research did not receive any grants from funding agencies in the public, commercial, or non-profit sectors.

Authors' contributions

Study supervision: Mohammad-Reza Vaez-Mahdavi and Hossein Hassanpour; Funding and resource provision: Vaez-Mahdavi; Methodology conceptualization and project administration: Hossein Hassanpour; Literature review, original manuscript drafting, and figures preparation: Leila Nasiri and Reyhane Najmi-Afshord; Review, editing and final approval: All authors.

Conflicts of interest

The authors declared no conflicts of interest.

Acknowledgements

The authors thank the Immunoregulation Research Center of Shahed University to support this study.

References

[1] Smith SB. Patriotism as loyalty. Social Research: An International Quarterly. 2019; 86(3):583-605. [DOI:10.1353/sor.2019.0030]

[2] Dietz MG. Patriotism: History and politics of a keyword. Handbook of patriotism. Berlin: Springer; 2020. [DOI:10.1007/978-3-319-54484-7_10]

[3] Turner BS. Cosmopolitan virtue: Loyalty and the city. In: Isin EFI, editor. Democracy, citizenship and the global city. Milton Park: Routledge; 2013. [Link]

[4] Kulchytskyi V, Sopiha M. Patriotism as the social value of the individual. Social Work and Education. 2018; 5(3):57-64. [DOI:10.25128/2520-6230.18.3.6]

[5] Poole R. Patriotism and nationalism. Milton Park: Routledge; 2016. [Link]

[6] Heinrich HA. Dimensional differences between nationalism and patriotism. Dynamics of national identity. Milton Park: Routledge; 2016. [DOI:10.4324/9781315746111-4]

[7] Soutphommasane T. The virtuous citizen: Patriotism in a multicultural society. Cambridge: Cambridge University Press; 2012. [DOI:10.1017/CBO9781139177740]

[8] Silvertown J, Silvertown JW. Selfish genes to social beings: A cooperative history of life. Oxford: Oxford University Press; 2024. [DOI:10.1093/oso/9780198876397.001.0001]

[9] Richter N. Facial resemblance and kinship detection by strangers. Encyclopedia of evolutionary psychological science. New York: Springer; 2021. [DOI:10.1007/978-3-319-19650-3_3751]

[10] Grosby SE. Time, kinship, and the nation. Genealogy. 2018; 2(2):17. [DOI:10.3390/genealogy2020017]

[11] Balliet D, Wu J, Van Lange PA. Indirect reciprocity, gossip, and reputation-based cooperation. In: Van Lange PAM, Higgins ET, editors. Social psychology: Handbook of basic principles. New York: Guilford Publications; 2021. [Link]

[12] Healy M. Patriotism and loyalty. Handbook of patriotism. New York: Springer; 2020. [DOI:10.1007/978-3-319-54484-7_18]

[13] Massaro AP, Gilby IC, Desai N, Weiss A, Feldblum JT, Pusey AE, Wilson ML. Correlates of individual participation in boundary patrols by male chimpanzees. Philosophical Transactions of the Royal Society of London. Series B, Biological sciences. 2022; 377(1851):20210151.[DOI:10.1098/rstb.2021.0151] [PMID] [PMCID]

[14] Mehta S. This land is our land: An immigrant's manifesto. New York: Random House; 2019. [Link]

[15] O'Mara SM. From 'Neurons to Nations': Neurocognitive foundations of nationalism. Neuroscience and Biobehavioral Reviews. 2026; 180:106482. [DOI:10.1016/j.neubiorev.2025.106482] [PMID]

[16] Flanagan B. Political Science and Testosterone. The Review of Politics. 2006;68(1):158-60. [DOI:10.1017/S0034670506310078]

[17] De Dreu CK, Greer LL, Handgraaf MJ, Shalvi S, Van Kleef GA, Baas M, et al. The neuropeptide oxytocin regulates parochial altruism in intergroup conflict among humans. Science. 2010;328(5984):1408-11. [DOI:10.1126/science.1189047] [PMID]

[18] Algoe SB, Kurtz LE, Grewen K. Oxytocin and social bonds: The role of oxytocin in perceptions of romantic partners' bonding behavior. Psychological Science. 2017; 28(12):1763-72. [DOI:10.1177/0956797617716922] [PMID] [PMCID]

[19] Gobrogge KL, Jia X, Liu Y, Wang Z. Neurochemical mediation of affiliation and aggression associated with pair-bonding. Biological Psychiatry. 2017; 81(3):231-42. [DOI:10.1016/j.biopsych.2016.02.013] [PMID] [PMCID]

[20] Terburg D, Van Honk J. Approach-avoidance versus dominance-submissiveness: A multilevel neural framework on how testosterone promotes social status. Emotion Review. 2013; 5(3):296-302. [DOI:10.1177/1754073913477510]

[21] Bakvis P, Spinhoven P, Roelofs K. Basal cortisol is positively correlated to threat vigilance in patients with psychogenic nonepileptic seizures. Epilepsy & Behavior. 2009; 16(3):558-60. [DOI:10.1016/j.yebeh.2009.09.006] [PMID]

[22] Daw ND, Tobler PN. Value learning through reinforcement: The basics of dopamine and reinforcement learning. Neuroeconomics. Amsterdam: Elsevier; 2014. [DOI:10.1016/B978-0-12-416008-8.00015-2]

[23] Duerler P, Vollenweider FX, Preller KH. A neurobiological perspective on social influence: Serotonin and social adaptation. Journal of Neurochemistry. 2022; 162(1):60-79. [DOI:10.1111/jnc.15607] [PMID] [PMCID]

[24] Charles SJ, van Mulukom V, Farias M, Brown J, Delmonte R, Maraldi E, et al. Religious rituals increase social bonding and pain threshold. PsyArXiv Preprints. 2020 [Unpublished]. [Link]

[25] McGaugh JL. Emotional arousal regulation of memory consolidation. Current Opinion in Behavioral Sciences. 2018; 19:55-60. [DOI:10.1016/j.cobeha.2017.10.003]

[26] Sibson A. The effects of endogenous and exogenous progesterone on ingroup affiliative bias [Honors Thesis]. Fayetteville: University of Arkansas; 2022. [Link]

[27] Yang J, Bellgowan PS, Martin A. Threat, domain-specificity and the human amygdala. Neuropsychologia. 2012; 50(11):2566-72. [DOI:10.1016/j.neuropsychologia.2012.07.001] [PMID] [PMCID]

[28] Feldt-Rasmussen U, Effraimidis G, Klose M. The hypothalamus-pituitary-thyroid (HPT)-axis and its role in physiology and pathophysiology of other hypothalamus-pituitary functions. Molecular and Cellular Endocrinology. 2021; 525:111173. [DOI:10.1016/j.mce.2021.111173] [PMID]

[29] Khayat A, Yaka R. Activation of nucleus accumbens projections to the ventral tegmental area alters molecular signaling and neurotransmission in the reward system. Frontiers in Molecular Neuroscience. 2024; 17:1271654. [DOI:10.3389/fnmol.2024.1271654] [PMID] [PMCID]

[30] Guu SF, Chao YP, Huang FY, Cheng YT, Ng HYH, Hsu CF, et al. Interoceptive awareness: MBSR training alters information processing of salience network. Frontiers in Behavioral Neuroscience. 2023; 17:1008086. [DOI:10.3389/fnbeh.2023.1008086] [PMID] [PMCID]

[31] Valentinova K, Acuna MA, Ntamati NR, Nevian NE, Nevian T. An amygdala-to-cingulate cortex circuit for conflicting choices in chronic pain. Cell Reports. 2023; 42(10):113125. [DOI:10.1016/j.celrep.2023.113125] [PMID] [PMCID]

[32] Wang MZ, Hayden BY, Heilbronner SR. A structural and functional subdivision in central orbitofrontal cortex. Nature Communications. 2022; 13(1):3623. [DOI:10.1038/s41467-022-31273-9] [PMID] [PMCID]

[33] Sun F, Yang T, Liu N, Wan X. The causal role of temporoparietal junction in mediating self-other mergence during mentalizing. Journal of Neuroscience. 2023; 43(49):8442-55. [DOI:10.1523/JNEUROSCI.1026-23.2023] [PMID] [PMCID]

[34] Ueda S. Oxytocin and the default mode network: New insights into attachment and self-referential processing. Galen Medical Journal. 2025; 14:e3812-e. [DOI:10.31661/gmj.v14i.3812] [PMID] [PMCID]

[35] Yao S, Kendrick KM. How does oxytocin modulate human behavior? Molecular Psychiatry. 2025; 30(4):1639-51. [DOI:10.1038/s41380-025-02898-1] [PMID]

[36] Geys B, Konrad KA. Patriotism and taxation. Handbook of patriotism. New York: Springer; 2020. [DOI:10.1007/978-3-319-54484-7_17]

[37] Zhang H, Gross J, De Dreu C, Ma Y. Oxytocin promotes coordinated out-group attack during intergroup conflict in humans. Elife. 2019; 8:e40698. [DOI:10.7554/eLife.40698] [PMID] [PMCID]

[38] Jurek B, Neumann ID. The oxytocin receptor: From intracellular signaling to behavior. Physiological Reviews. 2018; 98(3):1805-908. [DOI:10.1152/physrev.00031.2017] [PMID] [PMCID]

[39] Fitzduff M. Our brains at war: The neuroscience of conflict and peacebuilding. Oxford: Oxford University Press; 2021. [DOI:10.1093/oso/9780197512654.001.0001]

[40] Cheon BK. Gene-environment interactions on intergroup bias: the role of threat sensitivity and motivations for social affiliation [doctoral thesis]. Evanston: Northwestern University; 2012. [Link]

[41] de Jong TR, Neumann ID. Oxytocin and aggression. Current Topics in Behavioral Neurosciences. 2018; 35:175-92. [DOI:10.1007/7854_2017_13] [PMID] [PMCID]

[42] Sparapani S, Millet-Boureima C, Oliver J, Mu K, Hadavi P, Kalostian T, et al. The biology of vasopressin. Biomedicines. 2021; 9(1):89. [DOI:10.3390/biomedicines9010089] [PMID] [PMCID]

[43] Morse A. Mind-reading receptors: The role of the vasopressin receptor 1a gene (AVPR1A) in human empathy, social interaction and health [PhD Thesis]. Canberra: Australian National University; 2019. [Link]

[44] Beery A, Kamal Y, Sobrero R, Hayes LD. Comparative neurobiology and genetics of mammalian social behavior. In: Ebensperger LA, Hayes LD, editors. Sociobiology of caviomorph rodents: An integrative approach. Hoboken: John Wiley & Sons; 2016. [DOI:10.1002/9781118846506.ch3]

[45] Westfahl G. William Gibson. Champaign: University of Illinois Press; 2013. [DOI:10.5406/illinois/9780252037801.001.0001]

[46] Dass SAH. Role of arginine vasopressin in modulating plasticity in defensive behavior. Singapore: Nanyang Technological University; 2014. [Link]

[47] Vollebregt O, Koyama E, Zai CC, Shaikh SA, Lisoway AJ, Kennedy JL, et al. Evidence for association of vasopressin receptor 1A promoter region repeat with childhood onset aggression. Journal of Psychiatric Research. 2021; 140:522-8. [DOI:10.1016/j.jpsychires.2021.05.062] [PMID]

[48] Tan O, Bowen MT. The vasopressin V1A receptor and aggression: Challenges and potential novel treatments. handbook of anger, aggression, and violence. New York: Springer; 2023. [DOI:10.1007/978-3-030-98711-4_90-1]

[49] Rigney N, de Vries GJ, Petrulis A. Modulation of social behavior by distinct vasopressin sources. Frontiers in Endocrinology. 2023; 14:1127792. [DOI:10.3389/fendo.2023.1127792] [PMID] [PMCID]

[50] Moskalenko S, Kruglanski AW. Significance-questing or awe-stricken. In: Fujita K, Fishbach A, Liberman N, editors. The psychological quest for meaning. New York: Guilford Press; 2025. [Link]

[51] van der Meij L, Almela M, Hidalgo V, Villada C, Ijzerman H, van Lange PA, et al. Testosterone and cortisol release among Spanish soccer fans watching the 2010 World Cup final. PloS One. 2012; 7(4):e34814. [DOI:10.1371/journal.pone.0034814] [PMID] [PMCID]

[52] Casto KV, Edwards DA. Before, during, and after: how phases of competition differentially affect testosterone, cortisol, and estradiol levels in women athletes. Adaptive Human Behavior and Physiology. 2016; 2(1):11-25. [DOI:10.1007/s40750-015-0028-2]

[53] Neves T, Janeckova B, Lucká Y. The way of trauma. Trusting the course of change: A biosynthetic psychotherapy approach to the therapeutic work with trauma. Sabadell: Hakabooks; 2024. [Link]

[54] Bryan MB. The psychoneuroimmunology of perceived stress and chronic physiological stress as a threat to homeostasis [bachelor theses]. Sarasota: New College of Florida; 2017. [Link]

[55] Knight EL, Morales PJ, Christian CB, Prasad S, Harbaugh WT, Mehta PH, et al. The causal effect of testosterone on men's competitive behavior is moderated by basal cortisol and cues to an opponent's status: Evidence for a context-dependent dual-hormone hypothesis. Journal of Personality and Social Psychology. 2022; 123(4):693. [DOI:10.1037/pspa0000305] [PMID] [PMCID]

[56] Carré JM. Salivary testosterone and cortisol: Role of athletic setting, game outcome, and game location [master thesis]. St. Catharines: Brock University; 2007. [Link]

[57] Townsend SS, Major B, Gangi CE, Mendes WB. From "in the air" to "under the skin": Cortisol responses to social identity threat. Personality and Social Psychology Bulletin. 2011; 37(2):151-64. [DOI:10.1177/0146167210392384] [PMID] [PMCID]

[58] Bromberg-Martin ES, Matsumoto M, Hikosaka O. Dopamine in motivational control: Rewarding, aversive, and alerting. Neuron. 2010; 68(5):815-34. [DOI:10.1016/j.neuron.2010.11.022] [PMID] [PMCID]

[59] Jansen M, Overgaauw S, de Bruijn ER. L-DOPA and oxytocin influence the neural correlates of performance monitoring for self and others. Psychopharmacology. 2024; 241(5):1079-92. [DOI:10.1007/s00213-024-06541-9] [PMID] [PMCID]

[60] Chen W. Neural circuits provide insights into reward and aversion. Frontiers in Neural Circuits. 2022; 16:1002485. [DOI:10.3389/fncir.2022.1002485] [PMID] [PMCID]

[61] Mkrtchian A, Qiu Z, Abir Y, Erdmann T, Dercon Q, Sedlinska T, et al. Differential associations of dopamine and serotonin with reward and punishment processes in humans: A systematic review and meta-analysis. JAMA Psychiatry. 2025;82(8):818. [DOI:10.1001/jamapsychiatry.2025.0839] [PMID] [PMCID]

[62] Li M, Ren K, Cui C, Shi Y, Lei J, Li T, et al. VTA-ACC dopaminergic circuit mediates trait anxiety-related observational learning of social avoidance in male mice. Neuropsychopharmacology. 2025; 50(9):1364-75. [DOI:10.1038/s41386-025-02139-7] [PMID] [PMCID]

[63] Kulkarni G, Murala S, Bollu PC. Serotonin. Neurochemistry in clinical practice. New York: Springer; 2022. [DOI:10.1007/978-3-031-07897-2_2]

[64] Siegel JZ, Crockett MJ. How serotonin shapes moral judgment and behavior. Annals of the New York Academy of Sciences. 2013; 1299(1):42-51. [DOI:10.1111/nyas.12229] [PMID] [PMCID]

[65] Frey AL, McCabe C. Effects of serotonin and dopamine depletion on neural prediction computations during social learning. Neuropsychopharmacology. 2020; 45(9):1431-7. [DOI:10.1038/s41386-020-0678-z] [PMID] [PMCID]

[66] Schafer M, Schiller D. A dominant role for serotonin in the formation of human social hierarchies. Neuropsychopharmacology. 2022; 47(13):2177-8. [DOI:10.1038/s41386-022-01433-y] [PMID] [PMCID]

[67] Takeuchi H, Taki Y, Sekiguchi A, Nouchi R, Kotozaki Y, Nakagawa S, et al. Differences in gray matter structure correlated to nationalism and patriotism. Scientific Reports. 2016; 6(1):29912. [DOI:10.1038/srep29912] [PMID] [PMCID]

[68] Ni S, Guan L, Jin Y, Liu L, Zhu S, Zhao W, Palanirajan VK. Serotonin as a psychosocial biomarker in 3PM psychiatry: From the social brain to personalised intervention. The EPMA Journal. 2026; 17(2):295-324. [DOI:10.1007/s13167-026-00450-x] [PMID] [PMCID]

[69] Aan het Rot M, Moskowitz DS, Pinard G, Young SN. Social behaviour and mood in everyday life: The effects of tryptophan in quarrelsome individuals. Journal of Psychiatry and Neuroscience. 2006; 31(4):253-62. [DOI:10.1139/jpn.0629] [PMID] [PMCID]

[70] Dong J, Xiao T, Xu Q, Liang F, Gu S, Wang F, et al. Anxious personality traits: Perspectives from basic emotions and neurotransmitters. Brain Sciences. 2022; 12(9):1141. [DOI:10.3390/brainsci12091141] [PMID] [PMCID]

[71] Pozder D. The ethnicity of neurons: Nationalism a self-esteem of fools. Bloomington: Xlibris Corporation; 2023. [Link]

[72] Krishnan A. Havana syndrome: A threat to national security. London: Bloomsbury Publishing USA; 2025. [DOI:10.5040/9798216277033]

[73] Terbeck S, Savulescu J, Chesterman LP, Cowen PJ. Noradrenaline effects on social behaviour, intergroup relations, and moral decisions. Neuroscience & Biobehavioral Reviews. 2016; 66:54-60. [DOI:10.1016/j.neubiorev.2016.03.031] [PMID] [PMCID]

[74] Wang P, Wang SC, Liu X, Jia S, Wang X, Li T, et al. Neural functions of hypothalamic oxytocin and its regulation. ASN Neuro. 2022; 14(1):17590914221100706. [DOI:10.1177/17590914221100706] [PMID] [PMCID]

[75] Terbeck S, Kahane G, McTavish S, Savulescu J, Cowen PJ, Hewstone M. Propranolol reduces implicit negative racial bias. Psychopharmacology. 2012; 222(3):419-24. [DOI:10.1007/s00213-012-2657-5] [PMID] [PMCID]

[76] Mather M, Clewett D, Sakaki M, Harley CW. Norepinephrine ignites local hotspots of neuronal excitation: How arousal amplifies selectivity in perception and memory. Behavioral and Brain Sciences. 2016; 39:e200. [DOI:10.1017/S0140525X15000667] [PMID] [PMCID]

[77] Sun Q, Li G, Zhao F, Dong M, Xie W, Liu Q, et al. Role of estrogen in treatment of female depression. Aging. 2024; 16(3):3021. [DOI:10.18632/aging.205507] [PMID] [PMCID]

[78] Lawal OO, Lin D, Lischinsky JE. Estrogen control of social behaviors. Annual Review of Neuroscience. 2025; 48(1):125-47. [DOI:10.1146/annurev-neuro-112723-041639] [PMID] [PMCID]

[79] Caldbick E. The relationship between social cognition, sex steroids, and economic decision-making [PhD Thesis]. Burnaby: Simon Fraser University; 2023. [Link]

[80] Knight EL, Mehta PH. Hormones and hierarchies. The psychology of social status. New York: Springer; 2014. [DOI:10.1007/978-1-4939-0867-7_13]

[81] Choleris E, Ogawa S, Kavaliers M, Gustafsson JÅ, Korach K, Muglia L, et al. Involvement of estrogen receptor α, β and oxytocin in social discrimination: A detailed behavioral analysis with knockout female mice. Genes, Brain and Behavior. 2006; 5(7):528-39. [DOI:10.1111/j.1601-183X.2006.00203.x] [PMID]

[82] Lay NEPS. Engage the brain: How to design for learning that taps into the power of emotion. International Forum Journal. 2021; 24(1):246-9. [Link]

[83] Finke AV. Applying patriotic and national songs to american elementary music education curricular standards. Lynchburg: Liberty University; 2022. [Link]

[84] Zheng G, Han S. Distinct psychological and neural constructs of patriotism and nationalism. Cerebral Cortex. 2025; 35(9):bhaf268. [DOI:10.1093/cercor/bhaf268] [PMID]

[85] Lewis GJ, Kandler C, Riemann R. Distinct heritable influences underpin in-group love and out-group derogation. Social Psychological and Personality Science. 2014; 5(4):407-13. [DOI:10.1177/1948550613504967]

[86] Segal NL. Born together-reared apart: The landmark Minnesota twin study. Harvard: Harvard University Press; 2012. [DOI:10.4159/harvard.9780674065154]

[87] Settle JE, Dawes CT, Fowler JH. The heritability of partisan attachment. Political Research Quarterly. 2009; 62(3):601-13. [DOI:10.1177/1065912908327607]

[88] Howarth ER, Szott ID, Witham CL, Wilding CS, Bethell EJ. Genetic polymorphisms in the serotonin, dopamine and opioid pathways influence social attention in rhesus macaques (Macaca mulatta). Plos One. 2023; 18(8):e0288108. [DOI:10.1371/journal.pone.0288108] [PMID] [PMCID]

[89] Fog A. Warlike and peaceful societies: The interaction of genes and culture. Cambridge: Open Book Publishers; 2017. [DOI:10.11647/OBP.0173.0066]

[90] Durham WH. Toward a coevolutionary theory of human biology and culture. Biology and the social sciences. Milton Park: Routledge; 2019. [DOI:10.4324/9780429048531-8] [PMID]

[91] Sapolsky R. This is your brain on nationalism. Foreign Affairs. 2019; 98(2):42-7. [Link]