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## Neurobiology of Gender Identity Insights from Human Studies

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### Introduction

Gender identity represents an individual's deeply held sense of being male, female, a combination of both, neither, or another gender altogether. It is a core element of personal identity and typically emerges early in life, remaining stable in the majority of individuals across time. While historically examined through psychological and cultural frameworks, recent scientific developments have sparked increasing interest in the biological dimensions of gender identity. The evolving discipline of gender identity neurobiology aims to uncover the brain-based mechanisms that underlie the development and experience of gender identity, with a

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strong emphasis on evidence from human-based research.

This shift toward a biological perspective has been driven by clinical insights from individuals experiencing gender incongruence—where one's gender identity does not align with their assigned sex at birth—as well as by findings from studies on intersex conditions, neurodevelopment, and prenatal hormonal effects. With the advent of advanced neuroimaging techniques, such as MRI, fMRI, and DTI, researchers have been able to examine the human brain in greater detail, revealing patterns that may help explain the biological underpinnings of gender identity.

Studies involving transgender individuals have reported that specific brain structures—such as regions within the hypothalamus or cortical areas—often resemble those typically observed in individuals who share their identified gender, rather than those who share their natal sex (Burke et al. 2017). These discoveries imply that gender identity may be linked to distinct neurological features, potentially influenced by genetics, prenatal hormone exposure, and epigenetic factors during key stages of brain development. There are interactions between sexual orientation and gender in specific brain regions—including the left inferior frontal gyrus, both temporal lobes, and the right rostral anterior cingulate cortex—which are believed to play a crucial role in the sexual differentiation of the human brain (Wang et al. 2020). Although these findings are compelling, the field of gender identity neurobiology remains in a formative stage, characterized by complexity and the need for further exploration. Challenges such as small sample sizes, ethical concerns, and the necessity for inclusive research populations highlight the importance of careful study design. Integrating biological data with psychological, social, and cultural insights is essential for a holistic understanding of gender identity.

This article aims to present an overview of current findings from human neuroimaging and neurodevelopmental studies, explore the possible neurobiological correlates of gender identity, and discuss their broader implications for medical care, public policy, and social attitudes toward gender diversity.

## Brain Structures and Gender Identity

The human brain displays several sexually dimorphic traits—structural and functional characteristics that typically differ between males and females. These variations are believed to arise due to the influence of sex hormones during sensitive stages of both prenatal and postnatal brain development. Interestingly, many of the brain regions known to be sexually dimorphic also appear to be involved in the formation and expression of gender identity.

### 1. Sexually Dimorphic Brain Areas

One of the most studied areas in this regard is the bed nucleus of the stria terminalis (BNST), particularly its central subdivision (BSTc). This brain region plays a significant role in modulating stress responses, reproductive behavior, and social interaction. Research has shown that the BNST is typically larger and more neuron-rich in cisgender men compared to cisgender women. However, in transgender women (those assigned male at birth but who identify as female), the BNST often mirrors the structure observed in cisgender women, even before the initiation of hormone therapy. This observation suggests that the BNST may align more closely with a person's gender identity than with their biological sex (Frigerio *et al.* 2021). Brain functional organization of GD AFAB was generally more similar to that of cisgender girls than cisgender boys (Skorska *et al.* 2022).

Other regions of interest include the interstitial nuclei

of the anterior hypothalamus (INAH), which also display sex-related differences and have been found to vary in transgender individuals in a manner that corresponds with their identified gender (LeVay, 1991). These nuclei are known to influence sexual behaviors and hormone-related functions, making them relevant to gender identity development.

## ***2. Cortical Structure and White Matter Connectivity***

In addition to subcortical regions, cortical areas and white matter pathways have shown variation that may be linked to gender identity. Brain imaging studies using MRI and diffusion tensor imaging (DTI) reveal that transgender individuals often exhibit cortical and white matter features that are either intermediate between cisgender males and females or closely match those of their identified gender (Burke et al. 2017). For example, transgender men (assigned female at birth) have shown white matter microstructure patterns that are more consistent with cisgender men, particularly in brain areas associated with body perception and spatial orientation. Findings indicate that the cortical structure of adolescents with gender dysphoria who were assigned female at birth (GD AFAB) aligns with their experienced gender, particularly in relation to age-related changes in sexual attraction during adolescence—changes that are primarily reflected in brain tissue microstructure (Skorska, 2021).

Notable findings also include differences in cortical thickness within regions such as the prefrontal cortex, insula, and occipital-parietal lobes—areas involved in self-perception, emotional processing, and social awareness. These regions are considered central to the internal experience of gender and may reflect the neurological basis of gender identity.

### **3. Brain Structure Consistent with Gender Identity**

Across various studies, a consistent observation is that transgender individuals often possess neuroanatomical characteristics that align more closely with their experienced gender rather than with their assigned sex at birth (Zhou *et al.* 1994). Importantly, these traits have been identified in some cases prior to hormone therapy, suggesting that they may arise from early neurodevelopmental processes. Factors such as prenatal hormone exposure, genetic predispositions, and epigenetic regulation are likely contributors to these differences, pointing toward a biological foundation for gender identity.

## **Hormonal Influences on the Development of Gender Identity**

Hormones play a pivotal role in the biological processes that contribute to gender identity formation, especially during critical stages of brain maturation. The impact of sex hormones during prenatal and pubertal periods has become a central area of investigation in neuroendocrinology and gender research. These hormonal inputs are thought to influence how neural circuits are organized—circuits that govern sex-related behaviors, cognitive patterns, and potentially, gender identity itself.

### **1. Influence of Prenatal and Pubertal Hormones on Brain Differentiation**

During fetal development, the brain undergoes sexual differentiation under the influence of steroid hormones—primarily testosterone and estrogen. In typical male development, a testosterone surge during the second trimester leads to masculinization of the brain, affecting areas such as the hypothalamus, amygdala, and certain cortical structures. Conversely, in the absence of elevated testosterone, brain development follows a more typically

female pathway.

Although ethical constraints limit direct experimentation in humans, animal studies and indirect human research provide strong evidence that variations in prenatal hormone exposure can shape gender-typical behaviors and possibly influence gender identity. A second hormonal milestone occurs during puberty, when the brain and body are further shaped by gonadal hormones. While puberty brings about changes in physical appearance and emotional regulation, many scientists suggest that the foundational aspects of gender identity are primarily established during prenatal development, with puberty serving as a reinforcing phase rather than a determining one.

## ***2. Insights from Intersex Variations: CAH and AIS***

Additional understanding of hormonal effects comes from individuals with intersex conditions, where sex hormone production or response pathways diverge from typical patterns. Two widely studied conditions in this context are:

- ❖ **Congenital Adrenal Hyperplasia (CAH):** A condition in which genetic females (46, XX) are exposed to excess androgens in utero. Research shows that females with CAH are more likely to show masculine-typical interests and behaviors. While most still identify as female, a minority report experiencing gender dysphoria or identify outside the binary, indicating that prenatal androgen exposure may have a lasting impact on gender identity in certain cases (Seneviratne and Sumudu, 2021).
- ❖ **Androgen Insensitivity Syndrome (AIS):** In this condition, individuals with an XY chromosome pattern have a genetic variation that makes their cells partially or fully unresponsive to androgens.

Those with complete AIS (CAIS) typically develop female-typical anatomy and are raised as girls. Despite having internal testes and an XY karyotype, the majority identify as female, which supports the view that brain exposure to androgens—not chromosomal sex—is more influential in shaping gender identity (Gottlieb and Trifiro, 1999).

These case studies underline the role of early hormonal influences in the shaping of gender identity. However, they also emphasize that this is not a deterministic process—factors such as genetics, individual brain sensitivity to hormones, and social environments interact in complex ways to influence the trajectory of gender identity development.

## **Functional Brain Imaging and Cognitive Correlates of Gender Identity**

Advancements in functional brain imaging, especially functional Magnetic Resonance Imaging (fMRI), have deepened our understanding of how the brain processes gender identity. While structural imaging provides a static snapshot of brain anatomy, functional imaging allows researchers to observe dynamic brain activity during various cognitive and emotional tasks. However, brain function in transgender individuals often reflects their experienced gender, rather than the sex they were assigned at birth.

### ***1. Functional Imaging in Gender Perception, Voice Processing, and Emotional Interpretation***

Functional imaging techniques have been applied to investigate how individuals process gender-specific stimuli, such as faces, voices, and emotional expressions. These experiments typically engage brain systems responsible for social recognition, self-awareness, and emotional evaluation, all of which are integral to how one

experiences and expresses gender.

- ❖ **Gender Perception Tasks:** Studies utilizing gendered visual or auditory stimuli—such as photographs of faces or gender-typed body images—have shown that transgender individuals tend to activate brain regions in a pattern that matches their identified gender. For example, in categorization tasks using gendered faces, transgender women often show activation in areas associated with cisgender female processing patterns (Fisher *et al.* 2020).
- ❖ **Voice Recognition Studies:** Tasks involving gender-specific voices highlight how the brain decodes and categorizes vocal cues. In such studies, transgender individuals frequently exhibit neural responses in regions like the superior temporal gyrus and auditory cortex that are characteristic of their experienced gender, suggesting that auditory gender processing is closely linked to identity (Smith *et al.* 2018).
- ❖ **Emotional Processing Tasks:** When exposed to emotional facial expressions or emotionally charged scenarios, transgender individuals show activity in regions like the amygdala, insula, and anterior cingulate cortex that aligns more closely with their gender identity. These brain areas are crucial for affect regulation and empathic engagement, and their activation supports the emotional congruence with one's gender experience (Mansueto *et al.* 2024).

## ***2. How the Brain Supports Our Sense of Gender***

Our sense of who we are—whether we feel male, female, both, or neither—is deeply connected to how our brains work, not just how they look. Even before any kind of medical treatment, many people already show patterns in their brain activity that match the gender they feel



on the inside. This suggests that gender identity comes from within and isn't just shaped by outside influences. When people are simply resting and not doing anything specific, their brains still show certain patterns. These patterns, in many transgender individuals, seem to reflect the gender they identify with, not the one they were assigned at birth. This gives even more reason to understand gender identity as something real, natural, and deeply personal.

Rather than being about appearances or changes someone makes later in life, these brain patterns remind us that gender identity is often part of a person's inner world from early on. It's another way of showing that who we are inside is just as important—and real—as what others might see on the outside.

## **Neuropsychological and Behavioral Dimensions of Gender Identity**

Gender identity influences more than how a person sees themselves—it can also shape how they think, feel, and interact with the world. Instead of being strictly tied to the sex assigned at birth, the way people process information, express emotions, and behave often aligns more closely with their deeply felt sense of gender. For example, individuals who identify as women may show strengths in communication or emotional expression, while those who identify as men might display skills in tasks like spatial navigation. These patterns can often be observed in transgender individuals as well, whose thinking and behavior may reflect the characteristics traditionally associated with their identified gender.

Emotional traits such as empathy, sensitivity to others' feelings, and emotional awareness also tend to match one's gender identity. These tendencies are often visible from an early age—whether in the way children play, form friendships, or respond to social situations.

Overall, these patterns remind us that gender identity is not just about the body or external appearance. It is a deeply rooted part of who someone is—reflected in their thoughts, emotions, and everyday interactions. This perspective helps us appreciate the richness and complexity of human identity, encouraging greater understanding and respect for each person's unique experience of themselves.

### **Understanding Gender Identity: What It Means for Health and Society**

As we learn more about how gender identity is deeply rooted in who we are, it's becoming clear that this is not just a matter of personal choice or external appearance. For many people, their sense of being male, female, both, or neither is something that comes from deep within—and this understanding is changing the way we approach both healthcare and social attitudes. In everyday healthcare, recognizing that gender identity is a natural part of a person's makeup helps guide more thoughtful, respectful, and supportive care. When someone seeks support for things like counseling, hormone therapy, or surgery, they deserve to be treated with kindness and understanding—not judgment. Knowing that a person's identity comes from within can help doctors, nurses, and therapists offer the right care without making assumptions.

Outside of medical settings, this awareness also helps in shaping a fairer society. It can influence laws that protect people from discrimination, inspire schools to be more inclusive, and encourage workplaces to support everyone, no matter how they identify. When we understand that gender identity is part of human diversity, it becomes easier to move away from old stereotypes and toward acceptance.

In the end, seeing gender identity as something natural and real helps create a world where everyone can

live openly and authentically. It's about showing respect, offering support, and making space for every individual to be themselves.

## **Being Respectful and Responsible When Studying Gender and the Brain**

When exploring how the brain relates to gender identity, it's important that we do so with care, respect, and a strong sense of responsibility. For a long time, people who identify outside traditional gender norms—like transgender or non-binary individuals—have faced unfair treatment and misunderstanding. That's why it's essential to approach this topic in a way that values and respects everyone's experiences. Researchers and those talking about these issues should use thoughtful and inclusive language. It's also important to listen to and include people from gender-diverse communities in these conversations, instead of making assumptions based on old or limited ideas about gender. One big concern is that some people might misuse brain-related information to try to “prove” or “disprove” someone's gender identity. But gender identity isn't something that needs to be proven with brain scans. It's a personal truth—and science should help us better understand and support that, not box people in.

In the end, the goal of studying gender and the brain should be to build a kinder, more understanding world. It should help create better healthcare, more respectful policies, and greater acceptance. What matters most is that everyone feels seen, heard, and valued—just as they are.

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