New research has found that male and female brains are already different in the womb.

Research from the University of Cambridge shows that male and female brains develop differently as early as mid-pregnancy, opening up new insights into prenatal biology and autism.

For the first time, scientists at the University of Cambridge have tracked human brain development during a period previously studied only in fragmented ways: from mid-pregnancy to the first few weeks after birth. By linking pre- and postnatal brain scans, the research team found that measurable differences in how male and female brains develop appear as early as mid-pregnancy.

For years, scientists have debated when sex-related differences in the human brain begin to develop, as well as what biological factors are behind this phenomenon. Much of previous research has focused solely on the fetal or neonatal stages, inadvertently leaving a crucial blind spot: the period when the brain is rapidly reorganizing to adapt to life outside the womb. This lack of a continuous perspective has made it difficult for scientists to determine whether these differences only appear after birth, or whether they begin early and continue to expand over time.

To fill that gap, researchers at the Autism Research Centre at the University of Cambridge analyzed brain scans spanning both before and after birth. This allowed them to model early brain development as a continuous trajectory, rather than fragmented slices. This approach is particularly important because brain volume changes rapidly during this period, and small differences are easier to interpret when observing the entire growth curve over time, rather than just a single number.

The team's analysis is based on nearly 800 prenatal and postnatal brain images, sourced from the Developing Human Connectome Project – one of the largest perinatal brain imaging databases ever built. This scale is particularly significant in early developmental research, where individual differences are vast and mean differences are often quite subtle.

The human brain undergoes its most rapid and complex period of development before and immediately after birth. However, to date, we still know very little about exactly how the brain develops during this formative stage of life, and how males and females differ in this process. Our research has documented the existence of sex differences in brain development even before birth.

Sex differences in early brain growth

Published in the journal *Scientific Reports* , the research team stated that male brains experience a greater overall increase in volume as development progresses. On average, this difference is observed across the entire brain when compared to female brains at the same early developmental stage.

Dr. Alex Tsompanidis, Senior Research Fellow at the Center for Autism Research, shared:

> This research contributes to answering the long-standing question of whether natural factors play a role in shaping sex differences in the brain. The findings suggest that prenatal biology laid the groundwork for these differences, even as postnatal experiences continue to influence and modify them.

He added:

> The next step is to examine whether differences in brain growth between males and females are governed by prenatal sex hormones, such as testosterone and estrogen. Male fetuses are exposed to significantly higher levels of these hormones, and we know they play a crucial role in shaping brain and behavioral differences in many other animal species. The challenge is to determine whether the same is true in humans.

The study also yielded other important insights into how the brain develops in its early stages. For example, different brain regions and tissues mature at different rates. White matter – which connects brain regions – was identified as the primary contributor to brain growth during mid-pregnancy. Meanwhile, gray matter – involved in cognition and information processing – predominates in late pregnancy and after birth.

Furthermore, the research team found that early brain development is very tightly 'programmed' to meet the developmental needs of each stage. For example, subcortical gray matter structures (located deep within the brain such as the amygdala, cerebellum, and thalamus) peak their growth rate earlier than cortical gray matter. This suggests that brain systems responsible for basic functions mature earlier than those involved in higher-level cognition.

Implications for neurodevelopmental disorders

Dr. Richard Bethlehem, associate professor of neuroinformatics and a member of the research team, argues that establishing brain growth trajectories early in life is crucial because it can help understand how differences in early brain development contribute to diverse later outcomes, including psychiatric and neurodevelopmental disorders such as autism – a condition linked to differences in brain growth rates.

These findings may help us better understand why men and women differ in their likelihood of developing atypical neurological traits such as autism. For example, early brain differences may be linked to pre-existing sex hormones, with autistic individuals being noted for higher levels of these hormones. Future research needs to continue connecting these pieces in the promising field of developmental neuroscience.