

The Architecture of Human Sex, Perception, and Meaning

Developmental neurobiology, comparative embryology, probability, and optical perception, read through a community fabrication workshop in Korail, Dhaka.

PROJECT

Embryonic Shifts
Community fabrication workshop series
Stroboscopic Sculptural Zoetrope
Research into the Biological roots of Gender
Identity

STUDIO

Ghorar Dim Studios
Dhaka, Bangladesh

EDITION

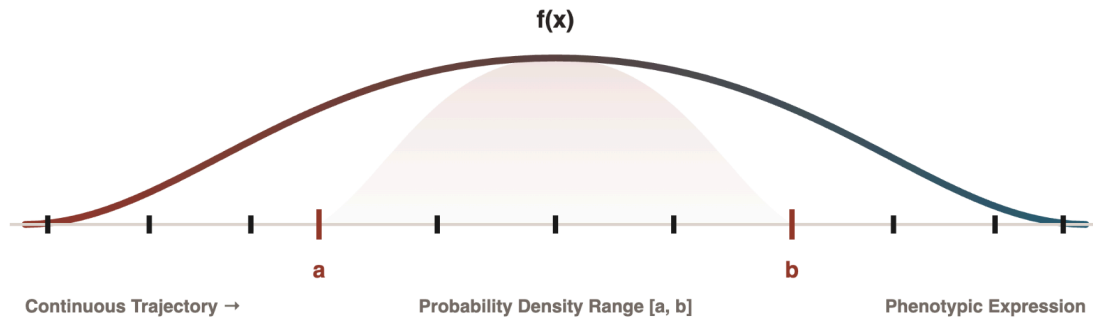
Verified draft · September 2026
See Appendix for verification notes

SUPPORTED BY

British Council Bangladesh
WOW (Women of the World) Foundation

PROBABILISTIC DISTRIBUTION & SPECTRUM MODEL

Biological Variation Represented as Continuous Density: $P(a \leq X \leq b) = \int_a^b f(x) dx$



1 Cellular, Chromosomal, and Comparative Embryological Mechanics

At the foundational level, our genetic blueprint is held within our chromosomes (tiny, thread-like structures inside every cell that carry the instruction manuals for building a body). While elementary education often presents a simple XX (female) or XY (male) binary, actual chromosomal mechanics display far greater diversity.

Aneuploidies (inheriting an unexpected number of chromosomes)

Variations such as Klinefelter syndrome (47,XXY) or Turner syndrome (45,X) demonstrate that an extra or missing sex chromosome shifts an individual's developmental trajectory without erasing their humanity. An individual with 47,XXY carries an extra X chromosome, which alters testosterone production during puberty; the great majority of people with this karyotype nonetheless grow up, and live, as men (Los & Ford, 2023).

Mosaicism (when a single body is made of two or more genetically distinct cell lines)

During early embryonic cleavage, chromosomes may segregate unevenly (mitotic non-disjunction), yielding a mosaic arrangement of cells with differing genetic profiles. A single person may therefore

carry 46,XY cells in some tissues and 45,X or 47,XXY cells in others. A body containing both 46,XX and 46,XY cell lines is usually a chimera, formed when two separately fertilised embryos fuse very early in development; the two mechanisms differ, but both produce one living person built from more than one genome.

Gynandromorphism (an organism possessing both male and female genetic and physical characteristics)

Observed strikingly in nature, such as in *Lycaeides* butterflies, this occurs when early embryonic errors leave an organism split, sometimes directly down the midline, with one half expressing male cellular genetics and the other female (Jahner et al., 2015).

Comparative Embryology and Points of Departure

During community engagements in Korail, Dhaka, exploring comparative embryology (the study of how different species develop as embryos) provided a powerful grounding for these concepts. In the early stages of vertebrate gestation—the pharyngula, or phylotypic, stage—the cellular structures across species (human, avian, fish, and reptilian) are remarkably similar. They share pharyngeal arches, rudimentary neural tubes, and undifferentiated gonadal ridges.

It is only later in development that specific genetic signals trigger embryonic points of departure, steering one path toward gills, another toward wings, and within humans, steering undifferentiated tissues toward male or female gonadal structures. Recognising that all human bodies pass through these shared embryonic origins underscores that sexual differentiation is a process of specialisation from a common cellular baseline, rather than two entirely separate blueprints.

Field Insights: The Korail Conversations and the Mechanics of Chance

Introducing these biological complexities through playful, game-based frameworks made abstract probability intuitive. By using familiar games like Ludo, community members explored how genetic, hormonal, and environmental variables interact prior to birth. In Ludo, the rolling of a six-sided die represents stochasticity (random probability governed by physical laws). A participant in Korail articulated this biological reality with remarkable clarity:

“It is true, some males have feminine characteristics while some females have male ones—I can see how it is like the dice of the Ludo board. We can strike the dice, but the outcome does not depend on us; it is determined by forces beyond us.”

WORKSHOP PARTICIPANT, KORAIL, DHAKA

Theoretical Modelling of Differentiation

In theoretical terms, human sexual differentiation behaves like a stochastic system governed by probability distributions rather than deterministic binaries. If we model fetal endocrine exposure as a random variable X with a continuous probability density function $f(x)$, the probability of a given developmental profile falling within a specific endocrine range can be written as:

$$P(a \leq X \leq b) = \int_a^b f(x) \, dx$$

THEORETICAL NOTE

This integral serves as a pedagogical and conceptual metaphor rather than a clinical formula. Sexual differentiation is a multi-variable process involving receptor sensitivity, timing, and genetic switches, so no single variable captures it. The expression nonetheless illustrates accurately how continuous biological inputs generate probabilistic spectrums rather than strict, binary outcomes.

2 The Prenatal Timeline: Decoupling Body and Brain

A critical insight from modern neuroendocrinology (the study of how hormones interact with the brain) is that the physical body and the brain do not differentiate at the same time. They unfold in two separate developmental windows during pregnancy (Swaab & Garcia-Falgueras, 2009).

The first trimester (the body)

Between roughly the sixth and twelfth weeks of gestation, genes like the SRY gene (Sex-determining Region Y, the master switch on the Y chromosome) trigger the development of testes or ovaries, and the external genitalia then form under the influence of gonadal hormones.

The second half of pregnancy (the brain)

Months later, a separate hormonal environment acts directly on the developing fetal central nervous system. This process shapes specific brain nuclei (clusters of specialised neurons deep in the brain) and establishes white-matter connectivity (the biological cables that connect different brain regions).

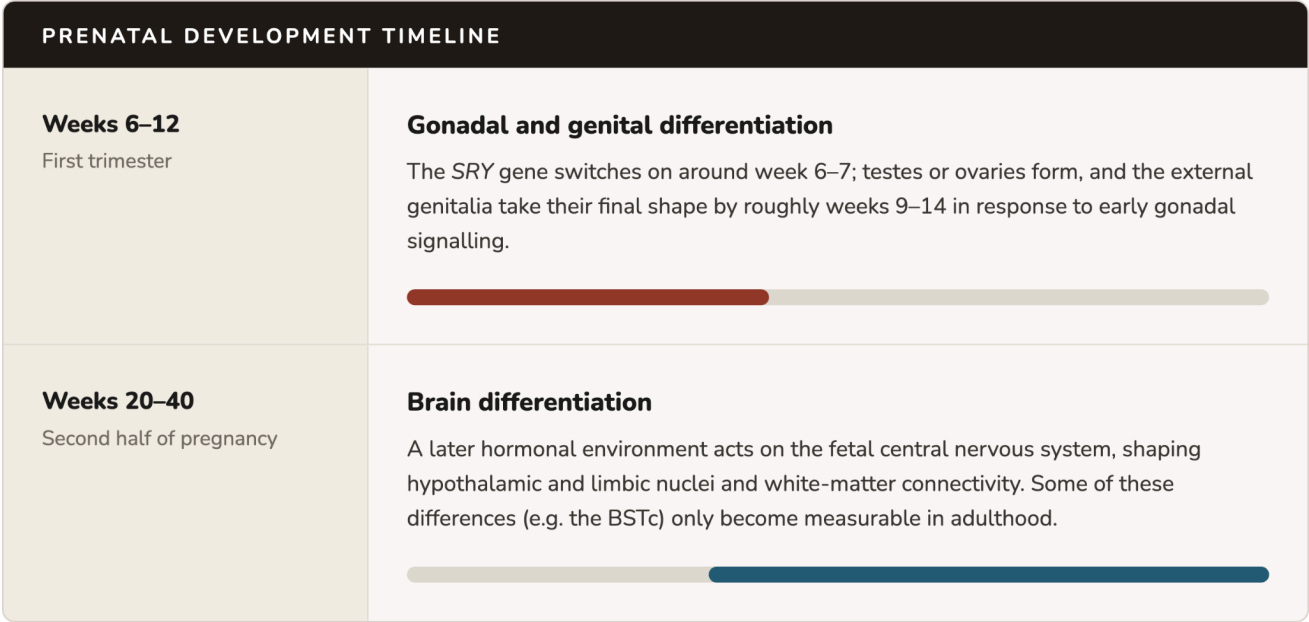


Figure 1. Two windows, months apart. Bars show approximate position within the 40-week gestation. Timing

follows Swaab & Garcia-Falgueras (2009): genital differentiation in the first two months, brain differentiation from the second half of pregnancy.

Because these processes occur months apart, atypical hormone pulses, maternal stress signals, or variations in cellular receptor sensitivity can shape a brain with an innate female identity inside a body with male external anatomy, or vice versa (Garcia-Falgueras & Swaab, 2008; Swaab & Garcia-Falgueras, 2009).

3 The Internal Coordinates: Body Schema and Identity

Deep within the brain live the structures that govern our internal sense of self and physical ownership.

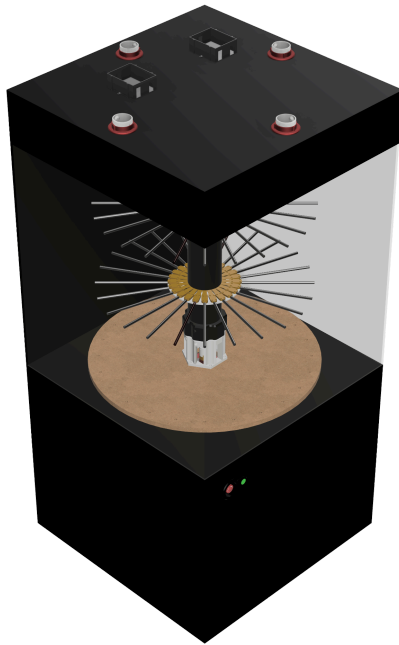
Brain Structure	Functional Role	Easy-to-Understand Translation
Somatosensory Cortex (S1)	Houses the homunculus map (a localized physical map of every body part).	<i>The brain's built-in map of where every limb lives.</i>
Temporoparietal Junction (TPJ)	Integrates sensory data to generate body ownership.	<i>The internal compass that says, "This body belongs to me."</i>
Bed Nucleus of the Stria Terminalis (BSTc)	Subcortical structure reflecting innate gender identity.	<i>A tiny control center holding your core sense of self.</i>
INAH-3	Sexually dimorphic nucleus regulating identity.	<i>A specialized neuron cluster tuned to identity and orientation.</i>
Salience Network (Insula & ACC)	Registers computational mismatches in sensory input.	<i>The brain's alarm system when something feels wrong.</i>

4 Perception as an Investigative Tool: The Zoetrope Metaphor

To explore how the brain constructs meaning from raw bodily signals, we can look to optical devices as playful metaphors for internal neurobiology. Rather than treating vision as an objective recording device, Embryonic Shifts asks the audience to interact with a sculptural zoetrope that uses strobing lights to investigate how perception begins inside the body—specifically through neural processing of raw sensory input.

Flicker, Fusion, and Neural Assembly

The zoetrope is traditionally explained by persistence of vision—the idea that the retina holds a faint trace of each image for a fraction of a second (a figure of about 1/16 of a second is often quoted) so that successive frames overlap. Modern perceptual science treats that account as incomplete. What actually makes discrete frames read as continuous movement is a pair of brain-level processes: flicker fusion, by which rapid pulses of light above a threshold rate are perceived as steady illumination, and apparent motion (the beta and phi phenomena), by which the motion-sensitive visual cortex infers movement between two still positions. The sculpture's strobe exploits exactly this: each flash freezes one frame, and the brain does the rest.



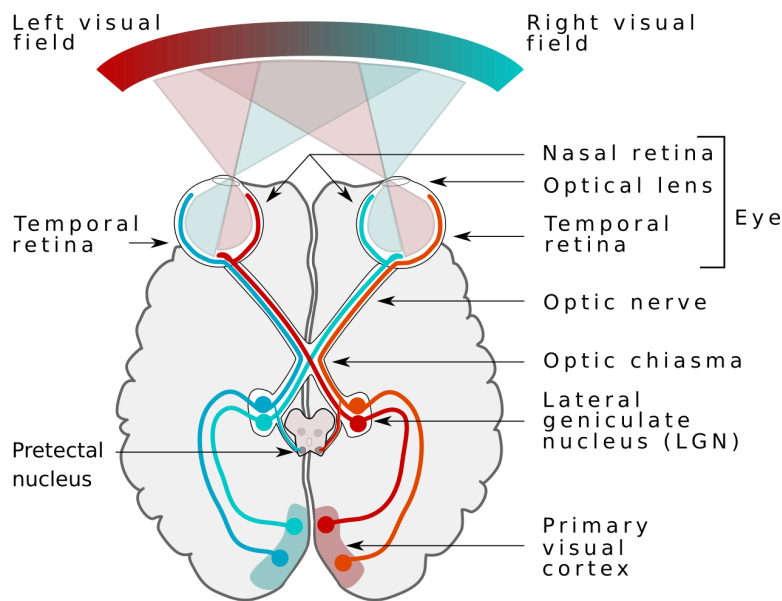


Figure 2

Static sculptures are “frames” separated by darkness which are attached to spokes as indicated on the image on the left; the motion between them exists only in the viewer.

As the contraption spins, individual static frames flash briefly under the strobe. Photons strike the retina (second image), where photoreceptors translate light into electrical signals sent along the optic nerve. The visual cortex—in particular the motion-sensitive V5/MT region—bridges the dark gaps, constructing a seamless perception of fluid motion inside the viewer's head. The motion does not exist on the sculptures; it is synthesised by the brain's predictive machinery.

Constructed Perception and Social Labels

Using the zoetrope as a framework demonstrates how perception begins inside bodily pathways. When observing other humans, the brain takes quick visual inputs—clothing, hair length, skeletal frame—and stitches them together into rapid categories like “male” or “female.” Just as the brain bridges the blank gaps in a zoetrope to construct motion, it uses visual shortcuts to construct social meaning. Sight alone cannot peer into subcortical nuclei (BSTc) or parietal maps. The zoetrope offers a playful lens to show that while perception begins with physical sensory inputs, the meaning we attach to those inputs is actively constructed within the brain. On the other hand, our body's mechanisms are also what is constructing how we are experiencing and processing sensorial stimuli. Interestingly, individuals with certain eye conditions or a varying image processing speed are unlikely to be able to view the illusion of motion, directly indicating how our bodies and its unique variations colour our experiences.

5 Cultural Overlays vs. Biological Inclinations

We must separate biological inclinations (innate motor and structural tendencies of the nervous system) from cultural overlays (arbitrary rules, symbols, and labels imposed by societies).

Motor propensities

Elevated prenatal testosterone shapes subcortical circuits, including the amygdala, inclining the young nervous system toward higher motor activity and spatial, object-oriented play; the same preference appears in rhesus monkeys, who have no exposure to human gender socialisation (Hines, 2006; Hassett, Siebert & Wallen, 2008).

Cultural constructs

While behavioural tendencies have biological roots, assigning manufactured items (plastic trucks vs. fabric dolls) or colours (blue vs. pink) is arbitrary. Society attempts to enforce a rigid binary on top of a continuous biological curve.

6 Regional History and Cultural Frameworks

In South Asia, modern social discourse often treats non-binary gender identities as recent novelties. Historical and legal records reveal a much richer narrative.

Long before colonial legislation introduced rigid legal frameworks—Section 377 of the Indian Penal Code (1860) and the Criminal Tribes Act (1871), which codified Victorian morals into law—the Indian subcontinent held established social roles for gender-diverse communities, including the Hijra and Kothi populations, among others (Reddy, 2005).

Classical Islamic jurisprudence (fiqh) historically devoted extensive study to the khuntha (individuals born with intersex characteristics), establishing legal guidelines for inheritance and social status based on functional biological traits (Sanders, 1991). Hostility surrounding human diversity in post-colonial societies is often less an expression of ancient culture than an inheritance of imported colonial law.

Brain structures and functional roles

BRAIN STRUCTURE	FUNCTIONAL ROLE	EASY-TO-UNDERSTAND TRANSLATION
Somatosensory cortex (S1)	Houses the homunculus map (a localised physical map of every body part).	The brain's built-in touchscreen map of where every limb lives.
Temporoparietal junction (TPJ)	Integrates sensory data to generate body ownership.	The internal compass that says, "This body belongs to me."
Bed nucleus of the stria terminalis (BSTc)	Subcortical structure whose volume, in adult post-mortem studies, corresponds to gender identity rather than birth sex.	A tiny control centre that tracks your core sense of self.
INAH-3	Sexually dimorphic hypothalamic nucleus whose volume is associated with gender identity and sexual orientation.	A specialised neuron cluster tuned to identity and orientation.

Salience network (insula & ACC)	Registers mismatches between expected and actual sensory input.	The brain's alarm sounding when something feels wrong.
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Somatosensory-mismatch model of dysphoria

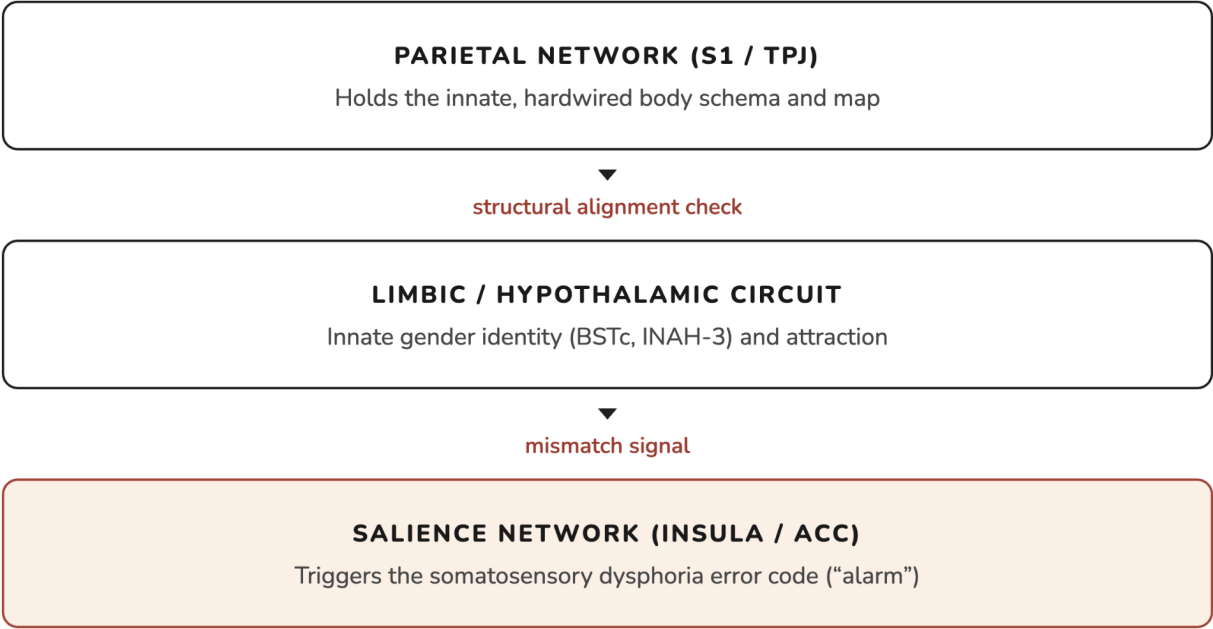


Figure 3. A schematic of the somatosensory-mismatch model of dysphoria. The circuit is a conceptual synthesis drawn from Ramachandran & McGeoch and Swaab's group; it is a working hypothesis, not a settled clinical mechanism.

Conclusion: Two Directions of Looking

A thaumatrope holds a bird on one face and a cage on the other. Spin it and the brain reports a bird in a cage—an image that exists on neither side. *Embryonic Shifts* is built on that fact, and it runs in two directions.

- Outward:** what we take to be simply seen is assembled. Motion in a zoetrope, a bird in a cage, a stranger's sex from hair and clothing—each is stitched from fragments and expectation. The eye delivers pieces; the mind completes them.
- Inward:** the fragments themselves have a history. Chromosomes come in more than one pair. Body and brain form in separate windows of pregnancy. The parietal map can expect a shape the skin never reports. Nothing here is a switch; it is a distribution. In Korail a Ludo die made that intuitive—the roll is real, unchosen, and no one's fault.

The difficulty is not the biology but the machinery built on it. Systems designed for two poles cannot see a spectrum, so they resolve it by force. Bangladesh recognised a third gender in 2013 but never defined it in law, leaving recognition to be administered through medical inspection. In 2024, a textbook story about a transgender girl joining the Hijra community was removed after protest. In 2025, World Athletics made a one-time gene test mandatory for the female category, and the IOC adopted the same rule for the 2028 Games; women born, raised and registered female now lose their events for carrying a gene they never knew they had. Each measure is procedural. Together they decide who can study, compete, work, or receive care. The same developmental account covers whom a person loves—the nuclei in Section 3 are associated with both—and the same principle holds: inner wiring is not a public decision.

None of this is new. Variation is older than the categories built to contain it, present in butterflies and embryos long before any statute. Biology has never treated the spectrum as a deviation from the norm; the spectrum is the norm, and the binary is one frequent outcome within it. A world order that reads the rest as anomaly—or, in its harsher registers, as perversion—has mistaken its own filing system for nature. It is the order that has to evolve, not the people it sorts. What the project offers toward that is not a verdict but an instrument: a disc, a die, a strobe, a diagram—each a way of watching one's own mind fill a gap, and then asking who benefits when the gap is filled one particular way.

Key Scientific Glossary

Aneuploidy — Having an extra or missing chromosome, such as three sex chromosomes instead of two.

Apparent motion (beta / phi) — The brain's inference of movement between two still images shown in quick succession; the real engine behind zoetropes and cinema.

BSTc (bed nucleus of the stria terminalis, central subdivision) — A cluster of cells deep in the brain whose volume, in adult post-mortem studies, corresponds to a person's gender identity rather than birth sex.

Chimerism — One body built from two genetically distinct zygotes that fused early in development; the usual origin of 46,XX/46,XY individuals.

Comparative embryology — The study of how different animal embryos develop, showing shared early cellular features before species-specific departures.

Flicker fusion — The rate above which pulsed light is perceived as continuous; the reason a strobe or projector does not look like a series of flashes.

Gynandromorphism — A rare biological condition where an organism contains both male and female genetic tissue.

Mosaicism — A condition where a single person is made of two or more genetic cell lines arising from one zygote.

Persistence of vision — The classical (and now incomplete) explanation that the eye retains an image for a split second, allowing discrete frames to blend into movement.

Somatosensory mismatch — The proposed neural alarm triggered when the brain's internal map of the body does not match physical feedback from the skin and limbs.

Stochastic system — A process governed by probability distributions and random variables rather than fixed, deterministic outcomes.

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A running list of the studies and references the writings are built on. It grows as the work grows.

Prevalence figures and estimates vary by source and population; ranges in the panels are approximate, given for context, not diagnosis.

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