How the Embryonic Chick Brain Twists

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Mechanics of Morphogenesis
Brain defects occur in approximately 1% of live human births.

Abnormalities in size and shape of the developing brain are known to cause serious neurological disorders:

- Anencephaly (missing part of brain)
- Hydrocephalus (swelling of brain)
- Autism
- Schizophrenia
- Mental retardation
Brain Development

Brain tube bends and twists.
(dorsal view)

~36 h ~40 h
~45 h ~52 h ~60 h
(dorsal view)
Brain Torsion

• One of the earliest organ-level left-right asymmetry event
• Inversed rotation associated with birth defects such as *situs inversus*
Mechanical Origins of Brain Torsion

Questions:
• What forces cause the brain to twist?
• What determines the direction of twist?
• Does bending affects torsion?
Heart Looping and Brain Torsion: Is there a connection?

Normal (right/right)

Abnormal (left/left)
Anatomic Observations
Effects of SPL on Looping Heart Tube

control

no SPL

30 hr  36 hr  +42 hr
Hypotheses

• The vitelline membrane constrains brain flexure, causing the brain to twist.

• The direction of the looping heart determines the direction of brain torsion.

• The degree of flexure affects brain torsion.
Effects of VM on Brain Torsion

Vitelline membrane is necessary for normal brain torsion.

Control

40h
L R
Dorsal view

57h
L R

- VM

40h
L R

57h
L R

68h
L R

+ ST

68h
Effects of Heart Looping Direction

Ventral view (48 hr)  Heart pushed to left.

Brain twists to left (60 hr).

Control
Effects of Heart Looping Direction

- Ventral view (52 hr)
- Heart pushed to left.
- Brain twists to left (60 hr).
- Control
Effects of Heart Looping Direction
Finite-Element Model

[Diagram showing a model with labeled parts: VM, Brain, R, L, Heart, and SPL]
Finite-Element Model
Effects of VM on Brain Torsion
Torsional angle
Relationship between flexure and torsion

Ventral view (41 hr)

An eye lash is implanted (59 hr).

Control
Relationship between flexure and torsion

Ventral view (38 hr)

An eye lash is implanted (58 hr).

Control
Summary

• The vitelline membrane supplies forces that cause the brain to twist in the chick embryo.
• The direction of heart looping determines the direction of brain torsion.
• The suppression of flexure reduces brain torsion.
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