Vertebrate origins and architecture
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Abstract

The following essay suggests vertebrates result from the expression of two cnidarian life stages simultaneously, one inside the other. A cnidarian polyp with its own fluid cavity is contained within a cnidaria planula. This is an extrapolation of Hans Mienhardt's thesis that the vertebrate body plan is an ancient hydra-like cnidarian. Anatomical and biochemical consideration reveals the neural tube is a fetus in fetu ancient hydra-like cnidarian polyp. The polyp foot and original oral opening are respectively the lamina terminalis, and the median and lateral apertures at the base of the cerebellum. Medusa buds at the base of the ancient hydra-like cnidarian polyp form the telencephalon, mamillary bodies, and hypophyseal stalk. The cranial nerves, cerebellum, tectum, and geniculate nuclei are vestiges of the polyp tentacles buds. The ancestral oral region has elongated to form the trunk and the mouth opening is the terminal ventricle of the spinal cord. The fetus in fetu host is an ancient cnidarian planula. The sympathetic trunks and peripheral ganglia are vestiges of the host cnidarian planula's segmented nervous system. The apical organ of the host cnidarian planula forms the olfactory epithelium and olfactory nerve. The hypothesized correlations are expanded upon and supported with references from the scientific literature.

Introduction

Cnidaria are aquatic animals characterized by an epithelium with a gastric cavity, tentacles, a nerve net with oral and/or basal nerve rings, and stinging cells. Cnidarian sense organs include statocysts, ocelli, and chemotactic organs. Morphologies of cnidaria vary between medusa, polyp, and planula body plans. Some species exhibit a single morphology and others have life cycles containing all three body plans. Reproductive methods also vary between sexual fertilization, asexual budding, regeneration following segmentation, and parasitic invasion.

Hans Meinhardt has outlined using gene expression data and mathematical modeling the vertebrate body plan emerged from a cnidaria hydra-like ancestor. (Meinhardt 2002; Meinhardt 2004; Meinhardt 2008, Meinhardt 2012). Meinhardt explicitly states the body pattern of hydra-like ancestral organism evolved into the brain of higher organisms. (Meinhardt 2012).

Gene expression patterns show most of the body of the hydra-like ancestor from the foot, body and including the tentacle area gave rise to the fore and midbrain in vertebrates. The narrow zone between tentacles and the gastric opening in the hydra gave rise to the trunk and anus. The border between the tentacle region and the hypostome are the mid/hindbrain region. The hypostome opening corresponds to the vertebrate anus During trunk extension, the tentacle boundary has been duplicated along each spinal chord segment. (Meinhardt 2002).

Meinhardt describes the entire vertebrate body plan as a single hydra. Alternatively, consider two cnidarian body plans exactly overlapping in their orientation and expression patterns. (Bottger 2012, Semmler 2010) An external planula body plan, with an internal hydroid polyp. The hydroid polyp is derived from the neural tube as a fetus in fetu contained within the CSF spaces. The planula posterior is oriented with the oral opening of the polyp which is consistant with the observation of reversal in cnidarian planula to polyp metamorphosis. (Rentzsch 2008, Groger 2001)
**Table 1:** Correlation of Cnidaria and Vertebrate anatomy

<table>
<thead>
<tr>
<th>Cnidaria Origin</th>
<th>Vertebrate Structure</th>
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<tbody>
<tr>
<td>polyp body</td>
<td>midbrain and spinal cord</td>
</tr>
<tr>
<td>tentacle</td>
<td>cranial nerves, I-XII, ventral spinal motor neurons, cerebellum, lateral and medial geniculate nuclei, superior and inferior colliculi, pineal,</td>
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<td>medusa buds</td>
<td>telencephalon, mamillary body, and neural hypophysis</td>
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<tr>
<td>planula</td>
<td>trunk and limbs, autonomic and peripheral nervous systems, spinal dorsal sensory neurons</td>
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**Fetus in Fetu**

A fetus in fetu is defined as a fetal form with highly developed organogenesis and the presence of a vertebral axis. (Hoeffel 2000, Pang 2015) Fetus in fetu is distinct from the classification of tetratoma, which refers to a fetiform mass. (Hoeffel 2000, Pang 2015) Human fetus in fetu births are observed at a rate of 1 in 500,000. (Hoeffel 2000, Pang 2015) The aetiology of fetus in fetu births is unclear, some consider it a tetratoma and others an incomplete monozygotic twin. (Pang 2015) The parasitic twin theory suggests the second fetus installs and grows inside its partner, often within a capsule covering. (Hoeffel 2000) Human fetus in fetu is an example of vertebrates exhibiting two life stages, one inside another. Imagine an ancient fetus in fetu event where a cnidarian polyp life stage was expressed within a cnidarian planula. The cnidarian fetus in fetu conveyed a survival advantage, was perpetuated genetically, and gave rise to vertebrate evolutionary branch.

A second plausible origin for the inner cnidarian polyp is parasitic invasion of a one cnidaria into another. Examples of parasitic invasion within the Cnidarian phylum are the myxozoa subphylum and polypodium hydriforme, which invades fish oocytes. (Evans 2008) These are all examples of cnidaria which invade another host and incorporate into its life cycle. The potential vertebrate origin resulting from cnidarian invasion of a cnidarian host and subsequent integration of life cycles warrants further investigation.

**Embryology**

Cnidaria life cycles and development vary widely across species. For example, hydra vulgaris exists solely in a polyp form which may arise from budding or sexual reproduction. Electron microscopy and histology of the hydra vulgaris embryogenesis are similar to that of vertebrate neural tube development. (Martin 1997) In particular the simple high columnar epithelium and the similarity of the cuticle to the vertebrate dura mater. (Martin 1997, Boelsterli 1977)

In other cnidaria, embryogenesis instead results in planula formation. During metamorphosis from planula to polyp, glwamide induces polyp formation and extension, and also initiates settling behavior. (Takahashi 2011, Martin 1997, Yuan 2008, Raikova 2013) Hydra GLWamide peptides also induce the metamorphosis of H. serrata planula larvae into polyps. (Takahashi 2015)

In vertebrate development, the host cnidarian planula embryo progresses and forms the neural plate. Induction of the neural fold and neural tube mark the initial expression of the guest cnidarian polyp fetus in fetu. The site of the initial neural fold is marked by longitudinal glwamide fiber staining ventral to the central canal. (Hamaguchi-Hamada 2009) The location of glwamide
expression down the midline of the neural tube combined with the similar histology of hydra embryogenesis support the concept of the entire neural tube as a cnidarian polyp induced to settle from the neural plate by glwamide signaling. A single genetic mutation related to glwamide expression could give rise to the vertebrate evolutionary branch.

Lastly, the clustering of neuropeptides across metazoan shows glwamide clustering in the vertebrate lineage. The presence and prominence of the clustering supports a central role for glwamide in development. (Jekely 2013)

Ancient Hydra-like Polyp Body - Vertebrate midbrain and spinal cord

The hydroid nervous system is characterized by a diffuse nerve net and variably present hypostomal and basal nerve rings which stain with the neuropeptide RFamide. (Grimmelikhuijzen 1995, Koizumi 2002, Koizumi 2004). Rfamide neurons are also concentrated in basal and hypostomal areas of hydra polyps. (Koizumi 2007) A high density of sensory cell bodies at the apex of the hypostome with neurites that run down to the base of the tentacles radially. (Koizumi 2007) Koizumi has proposed the hydra nerve ring is the origin of the central nervous system of bilaterian animals. (Koizumi 2007).

Five classes of vertebrate Rfamides are known. (Sandvik 2014) Rfamide peptides expressed at a very early stage in most vertebrates studied, but much data. (Sandvik 2014). Distribution of 26RFa receptor and GPR103 mRNA supports location of neurotransmitter pool in the brainstem and cortex as medusa bud. (Bruzzone 2007).

Several neuroanatomical landmarks correlate the nervous system of the hyrdra-like ancestor to the vertebrate central nervous system. The linea terminals of the brainstem forebrain boundary is the polyp foot. The original hydroid oral opening is at level of the foreamen of lushka in the brainstem.

Neurons of the isodendritic core of Ramon-Moliner and Leontovich are the vestige of the rfamide staining neurons of the hydroid polyp. (Leontovich 1963, Ramon-Moliner 1966) The isodendritic core is an anatomical concept, defined by dendro architectonics, which classifies brain regions according to dendritic morphology. (Mannen 1960, Leontovich 1963, Ramon-Moliner 1966). Nuclei and cortical regions which consist of neurons with an isodendritic morphology are considered an organizational unit. Isodendritic nuclei are found throughout the brainstem with overlapping dendritic fields and axons that bifurcate and project broadly. Isodendritic neurons are also found scattered within in other nuclei and cortical regions. (Leontovich 1963, Ramon-Moliner 1966)

Thalamic reticular nucleus and the intrlaminar nuclei of the interthalamic adhesion are isodendritic and demarcate the basal nerve ring. (Leontovich 1963, Malobabic 1990) Within the spinal cord, the isodendritic lamina VII is the vestige of the extended stomal nerve ring. (Schoenen 2004) In cniarian hydra, the stomal nerve ring functions to coordinate crumpling behavior. (Koizumi 2007) The vertebrate isodendritic core similarly coordinates inputs from the vestige tentacle regions.

The non-neuronal cells of the hydra evolved into the spectrum of other neural and supporting cells that makes up the central nervous system. The histology of the central nervous system should thus be reconsidered in terms of polyp and planula derivatives. For example, the mesodermal and neural crest cells which migrate into the central nervous system and form the glia, dura, arachnoid, and pia matter are planula derivatives.

The dural spaces provide an isolated water compartment for the polyp. The third and forth ventricle,
spinal canal, and CSF spaces correspond to the gastric cavity of the ancient hydra-like ancestor. In cnidarian budding polyps, the stalk and bud cavities are in communication following Frey stage 5/6 of development. (Frey 1968) The telencephalon buds similarly communicate via the third and lateral ventricles. The terminal ventricle is the patent opening of the spinal canal into the CSF space of the spinal cord. This is the extended oral opening of the primary polyp. (Coleman 1995)

The parent polyp stalk and bud also communicate via nerve projections. (Groger 2000) The vestige of the parent polyp to bud communication fibres in the vertebrate are the bundles of cortical projection neurons originating from the brainstem isodendritic core. (Theofilas 2015) The isodendritic brainstem nuclei project and serve as a pool of neurotransmitters for the entire nervous system. (Rossor 1981, Pasquier 1977)

Ancient Polyp Tentacles – Vertebrate cerebellum, cranial nerves, geniculate nuclei, and tectum

In the vertebrate brainstem, the dorsal midline is the location of structures related to hydroid polyp tentacle formation. (Jacobs 2007) Meinhardt midline GSC expression outlines the zone normally adjacent to the tentacle zone extends down as a midline organizer form the hind brain boundary towards the lamina terminalis. (Meinhardt 2002) Meinhardt also describes the potential of tentacles to develop outside the tentacle zone following the removal of inhibiting factors. (Meinhardt 2012) Moreover, cnidaria medusa and polyp phenotypes have sense organs present at the tentacles base. (Muller 1861, Kramp 1961, Garm 2010) The rhodpalia and statocyst sense organs at the tentacle bases correspond in vertebrates to the medial and lateral geniculate, superior and inferior colliculi, pineal gland, and cerebellum.

The ancient hydroid polyp tentacles evolved into the cranial spinal nerves. Inner ear cellular development studies have confirmed the migration of cells from the neural tube into the otic cap. (Freyer 2011) VENT cell migration is vestigal migration of cells from the polyp body column along the tentacles and into the host cnidaria planula. (Dickinson 2004) This pattern of migration and host planula placode interaction is repeated by each of the special sensory cranial nerves. (Maiera 2014)

Unlike the other cranial nerves, the neural tube derived olfactory lobe emerges anteriorly from the telencephalon. The olfactory lobe thus corresponds to a primary tentacle extending from the superior portion of the medusa bell. An example of cnidaria demonstrating tentacles above the bell margin is Olindias formosa, the flower hat jelly. (Muller 1861, Kramp 1961) The tips of flower hat primary tentacles are fluorescent and used to attract prey. (Figoski 2005, Watts 2004, Shimomura 1962)

The olfactory epithelium and nerves are derived from the olfactory plate. (Treloar 2002, López-Mascaraque 2002, López-Mascaraque 2015) The epithelial portion of the olfactory nerve corresponds to the chemotactic apical organ of the planula. (Rentzsch 2008) The terminal nerve would speculatively have origins similar to the olfactory nerve. (Vilensky 2014) The pattern of migrating tentacle tissue from the hyrda-like polyp into the planula is otherwise similar to that observed by other cranial nerve systems.

The cerebellum develops from expansion of the dorsal rhombomere in the posterior lip of the brainstem at the junction of the mid and hind brain. (Butts 2014, Mitsuhiro 2012) The location of the median and lateral aperatures of the fourth ventricle mark the location of the original oral opening of the ancient hydra ancestor. (Meinhardt 2002) The genetic expression at the mid and hind brain boundary corresponds to the original tentacle zone. The cerebellar lobes are tentacle
buds which expanded with deep surface convolutions instead of growing longitudinally.

**Ancient Polyp Medusa Buds – vertebrate telencephalon, mamillary, and hypophysis**

Budding regions at base of the ancient hydroid polyp give rise to the telencephalic and midbrain vesicles. Visual inspection of the developing nervous system suggests the telencephalon vesicles are Frey stage 6 medusa buds with the stalk zone demarcated by the connection of the third and lateral ventricles. (Frey 1968, Boelsterli 1977, Groger 2000) Location of scattered reticular neurons in cortical layer VI, which projects back to the thalamus, and concentrations in the amygdala and septal nuclei suggest the location of the vestige bud rfamide nervous system. (Leontovich 1963, Groger 2000)

The central stalk forms at the foreman between the lateral and third ventricle. One tentacle bud and ring canal elongates into the temporal lobe and temporal horn of the lateral ventricle. The temporal lobe lateral fissure is the emerging space of the velum of the temporal tentacle bud. The growth of the second tentacle bud and ring canal is repressed and it appears as the occipital horn of the lateral ventricle and occipital lobe. White matter projections fill the endodermal and subumbrellar cavity of the medusa bud.

The cingulate, frontal and insular cortices are the bud manubrium. The frontal, parietal, temporal, and ocular cortex are the bud ectoderm. The caudate and putamen are the entocodon or forming subumbrellar plate. One can further consider the potential for choroid plexus to be prematurely emerging palps or oral arms of the medusa. This would also be consistent with the presence of choroid plexus in the medial and lateral apertures at the base of the cerebellum.

The mamillary bodies and hypophysis are located on the ventral surface of the brain. The presence of a stalk and lack of ventricular communication in indicate they are Bollesteri stage U3 buds. The bud to polyp fornix projections from the the hippocampus enter the polyp and exit again to terminate on the adjacent mamillary bud. The bud to polyp projections from the mamillary bodies terminate on the thalmus. (Groger 2000) Hypophysis bud development is influenced by adjacent planula tissue which results in the pituitary gland.

**Ancient Cnidaria Planula - vertebrate trunk, limbs, PNS, ANS, and sensory neurons**

The planaria phenotype is a worm like body with an orthogon nervous system composed of longitudinal chords and segmented commissures. (Mayorova 2013, Piraino 2011, Groger 2001)

Assuming the acoel is a frozen planula stage of a cnidarian, and a fetus-in-fetu cnidarian polyp is contained within it. The non neural tube embryonic derrivatives are all the ancient acoel-like animal. The neural crest derivatives are the orthogon of the ancient acoel-like ancestor nervous system. The sympathetic trunk and chain ganglia, and grey and white rami communicans are ladder like orthogon of ancient acoel-like ancestor. (Brinkmann 2007).

**Conclusion**

This commentary attempted to outline how vertebrate architecture and development could be interpreted as a cnidarian fetus in fetu. Examples were loosely incorporated from multiple cnidaria species in order to support the correlation of cnidarian and vertebrate anatomy. Vertebrates were broadly referred in order to suggest the outlined structures are in various Bollesteri and Frey
development stages across vertebrate species. No experimental or direct quantitative evidence has been provided. However, references are provided to support the comparisons and concepts. The above interpretation is a rough outline intended to provide concepts and references for rigorous investigation. Ideas for experiments include:

- Attempt to induce reverse medusa and polyp development of central nervous system of a developing vertebrate using cesium chloride. (Schmich 2007)
- Gene insertion in acorn worm to express a hym-248 glwamide in the midline during development. Attempt to trigger hydroid polyp embryonic development and form a neural tube.
- Isodendric confocal imaging studies using dual labeling of neuropeptides and lipoid staining to confirm neuron dendritic morphology correlation. (Obrien 2006)
- Isolate genetic components of fetus in fetu and midline glwamide expression, and trace across deuterostomes.

A cnidarian fetus in fetus interpretation of the nervous system can also yield novel interpretation of vertebrate nervous system architecture and attempts at artificial implementation.

The organization of the vertebrate nervous system can interpreted in terms of the cnidarian anatomy. A stimulus is received by host planula sensory cells and relayed through the host planula/guest polyp tentacle interface to the polyp sense organ ganglia at base of the polyp tentacle. The polyp rfamide nerve ring isodendric core coordinates the stimuli by generalized activation of the polyp nerve net. Diffuse polyp to medusa bud projections make a pool of neurotransmitters available to the medusa bud neurons. In addition, there is a projection from the nucleus at the tentacle base directly to the medusa bud tentacle. Medusa bud neurons which receive both stimuli simultaneously are activated.

Activated medusa tentacle bud neurons provide active center and negative surround feedback to the isodendritic core and inhibit other areas to focus on the active stimuli. Within the medusa bud neurons of the tentacle feed information forward along the medusa bud tentacle up to the medusa bud manubrium and bell neurons. Medusa bud to medusa bud projections cross via comissure tracts share stimuli across to the opposite hemisphere.

For example, visual light is received as inputs across massively parallel and spatially organized retina cells to obtain 3D phase and frequency encoded K space of the field of view. The inputs are relayed to the lateral geniculate nucleus of the thalamus and organized into a 3D space rip data arrangement in the superficial nuclei. (Kyriakosj 2000) The 3D space rip inverse calculation takes place in the deeper lateral geniculate layers. (Zhang 2011) The visual scene is projected to the primary visual cortex and used input to a deep neural network processing pipeline. (Schroff 2015)

En passant synapses of retina to lateral geniculate axons stimulate the isodendritic core which spreads via the diffuse axonal and dendritic pattern. Isodendritic brainstem projection nuclei broadly project neurotransmitters to the telencephalic cortex. Cortical layer VI neurons, including scattered isodendritic neurons, simultaneously stimulated by the isodendritic projections and deep neural network activation reach sufficient threshold to feedback to lateral geniculate and thalamus with center reward, lateral surround inhibition. (Lam 2010) The retinal and lateral geniculate input, isodendritic core stimulation, and cortical back projections sustain a feedback loop.

Perceptive awareness occurs when an activation pattern of cortical activation and feedback is sustained for a given input. The learned ability to maintain sustained inhibitive control over the layer VI cortical negative feedback projections is referred to as heightened awareness or enlightenment. (Harada 1998, Inoue 2007)
Attempts at artificial implementations of the CNS should consider the cnidarian analysis and use the isodendritic core to integrate the tiers of planula, polyp, tentacles, and medusa buds. After the isodendritic scaffold is worked out, sensory modalities can be added using the 3D space rip encoding and scaled to unprecedented scales of integration.

References


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