The morphogenetic school in the history of evodevo

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Evodevo as Evodevo genetics

- Gilbert, Carroll, Amundson
- Key issues: genetic pathways, master genes, cis-regulatory elements...
- The great synthesis: the population genetics of regulatory genes
Evodevo genetics history

Modern Synthesis

Developmental genetics
Lewis, Gehring, García-Bellido...

Evodevo
Evodevo genetics history

Mendel rediscovery

Transmission genetics
The chromosomal theory of sex determination
(Morgan and Wilson)

Experimental embryology

Physiological genetics
Goldsmitd, the genetics of induction,
Lac Operon

Developmental genetics
However...

- Wake, Oster, Goodwin, Kaufmann, Arthur, **Alberch**, Raff, Newman, Müller, Richardson & Chipman, Fusco, Salazar-Ciudad...

- **Key issues:** self-organization, developmental constraints, variability, novelty, modularity, evolvability...
Evodevo programs

- Morphology & Systematics
  - Gene regulation
  - Epigenetic
- Theoretical biology

(Müller & Newmann 2005)
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Morphology & Systematics

- Theoretical and Functional morphology, Paleontology, Comparative anatomy, Cladistics, Phylogenetics

- Typology, novelty, evolvability, homology, macroevolution, modularity...
Morphology & Systematics
  - Gene regulation
    - Epigenetic
- Theoretical biology
  (Müller & Newmann 2005)
Evodevo programs

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(Müller & Newmann 2005)
The epigenetic program

“The epigenetic approach investigates **the generic properties of developmental systems in the origination of novelty**, explicitly addressing the non-programmed aspects of development. This includes the physical properties of biological materials, the self-organizational capacities of cell and tissue assemblies, the dynamics of developmental interactions, the role of geometry and tissue architecture, the influence of external and environmental parameters, and all other factors that affect the development of organismal form...”
The morphogenetic tradition

• The **morphogenetic school** in experimental embryology and theoretical biology
  – The experimental embryology program
  – Epigenetics in the early experimental embryology
  – Biochemical embryology

• The **evolution of the morphogenetic level**
Experimental embryology

“the study of the laws of mechanics and chemistry to which the morphogenetic processes that form the morphologies are subjected.”

(Alberch 1998)
Roux Program
A mechanical approach to development

- Manipulative controlled experimentation
  - vs observation & description
  - Comparison % the experimental and normal cases.
  - tissue culture and embryonic transplantation
- General rules of mechanical causation:
  - determination & predictability
Experimental embryology

• Not just cytoplasm/nucleus debates

“When to satisfy our craving for causality, biologists transform the visible complexity of the adult organism into a latent complexity of the germ...” (Hertwig 1894, 140)

• Epigenetic theories
  – Cell level
  – Tissue level
The epigenetic program

- **Cell level**
  - Driesch: spatial relationships
    - The colonial growth patterns of hydrozoans and the mathematical frustration
    - Specialization as a function of blastomeres' positions.

- **Tissue level**
  - His Topological embryology (1874)
Biochemical embryology

- In search of “the laws of ordered form” (Needham 1931)
  - Induction and the organizer
  - The morphogenetic field
  - Harrison’s demonstration of limb polarity
  - Hamburger’s and Weiss’ studies on neuron growth and specificity
Induction and the organizer

- Herbst's and Driesch's formative stimulus
- Hörstadius and Child's Gradients
- Spemann, Needham, Waddington
- "evocator-competence system"
  - An unstable (i.e. multipotential) system which an inducer can push to one equilibrium or another.
The morphogenetic field

[A] system of order such that the positions taken up by unstable entities in one part of the system bear a definite relation to the position taken up by other unstable entities in other parts of the system. The field effect is constituted by their several equilibrium positions. A field is bound to a particular substratum from which a dynamic pattern arises. It is heteroaxial and heteropolar, has recognizably distinct districts, and can, like a magnetic field, maintain its pattern when its mass is either reduced or increased. It can fuse with a similar pattern entering with new material if the axial orientation is favorable.

(Needham 1950).
Organisms and Processes

- Dialectical materialism
- Whitehead philosophy of processes
- Organisms and cells as "systems" of interacting parts
- The epigenetic landscape, chreods and canalization
The evolution of the morphogenetic level
Experimental embryologists' synthesis

- Experimental embryology and Phylogenetics
  - Eugen Schulz (1905)
  - H. Braus’ Experimental morphology (1906)
The bilinguism of embryology

- Regeneration, homeosis, homology, atavism
  - Regenerative homeosis and phylogenetic causes
    (Loeb, Herbst, Spemann, G. Wolff)
  - Homeosis as atavism: Regeneration and recapitulation
    (Korschelt, 1927)
  - Paralelism between regeneration and evolution allows to compare teromorphs with normal primitive structures
    (Przibram, Kessler)
Cybernetics and Evolutionary Theory

- Schmalhausen:
  - *The Organism as a Whole in its Individual and Historical Development* (1938)
    - correlations (ontogeny) and coordinations (phylogeny)
- Waddington:
  - “Diachronic Biology”: an integration of genetics, evolution, and development (1975)
"I should like to see the present fashion for molecular genetics diluted by the diversion of rather more attention to fundamental embryology. Genetics has had its breakthrough, and those who want quick results can probably get them most easily by exploiting this. But the next breakthrough we need, to round off our understanding of fundamental biological processes, is an embryological breakthrough. Let us hope that we get it soon (1962)."