Complex systems approach in developmental biology

Cell differentiation and pattern formation

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Complex systems share several agreed-upon features.

- Multiple parts interact
- Interesting collective behavior
- Collective behavior not easily predicted from knowledge of the parts

Morphogenesis can be understood as the collective behavior of cells.

A complex systems perspective can inform several aspects of developmental biology.

Differentiated cells arise from distinct germ layers.
Differential gene expression from the same nuclear repertoire causes different cell phenotypes.

Gene expression can be regulated at several levels.
- Transcription
- Nuclear RNA processing
- mRNA translation
- Protein modification

Regulation of gene expression can be understood as a network.

A few discrete cellular processes underlie morphogenesis.
- Direction and number of cell divisions
- Cell shape changes
- Cell migration
- Cell growth
- Programmed cell death
- Changes in the composition of the cell membrane or secreted products

Mitosis produces more cells (hyperplasia)
- Limb mesenchyme

Cells die
- Interdigital mesenchyme

Cells grow larger (hypertrophy)
Discrete cellular processes are coordinated by signal transduction.

- Signal transduction pathways
- Cascades of inductive events
- Pattern (organ) formation

Development was largely ignored during the modern synthesis.

Development | Natural Selection
---|---
Generation 1 | Genotypes → Phenotypes → Fitness
Generation 2 | Genotypes → Phenotypes → Fitness

Adapted Population

Complex systems approach to the evolution of development?

- Developmental constraint or bias?
- Development (and GRN) as the product of evolution?

Images:
5. Gilbert 2006, p. 4
9. DeLeon and Davidson 2007
10. rudel_and_sommer_2003.jpg
11. Rudel and Sommer 2003, Gilbert 2006, p.147
13. Davidson and Erwin 2006

Sources:
- Levine and Davidson (2005) Gene regulatory networks for development. PNAS 102, 4936-4942