The Anatomical Tradition

September 7, 2006
A hen is only an egg’s way of making a new egg.

Samuel Butler, 1885
Fundamental Questions:

How does a fertilized egg give rise to the adult body?

Life Cycle

How does the adult body produce yet another body?
General Questions:

1. Each adult cell type contains the same DNA. How do they turn into different types of cell? **[Differentiation]**

2. Differentiated cells are organized into tissues and organs; organs are arranged in a given way. How does this happen? **[Morphogenesis]**

3. How do cells know when to stop dividing? **[Growth]**

4. Sperm and eggs are extremely specialized. How is gametogenesis accomplished? **[Reproduction]**

5. How do changes in development create new body forms? **[Evolution]**

6. How is development of an organism integrated into the larger context of its habitat? **[Environmental integration]**
Scientific Approaches

Comparative embryology (historic)

Experimental embryology (modern)

Evolutionary embryology

Teratology

Mathematical modeling
Comparative Embryology
Comparative Embryology

Hippocrates (5th century BCE) - recognized development

*Aristotle (4th century BCE) - cleavage patterns, viviparity, etc.

William Harvey (1640s) - *Ex ovo omnia* (“all from the egg”)

Marcello Malpighi (1672) - 1st microscopic account of chick development

Kaspar Friedrich Wolff (1733-1794) - differentiated tissues arise from undifferentiated cells

Christian Pander (c. 1817) - germ layers, induction

Heinrich Rathke (1820’s) - similarity between species

Karl Ernst von Baer (1820’s) - described blastula, notochord, mammalian egg; established “von Baer’s laws”
Origins – Epigenesis v. Preformation

epi- “after” (or upon, over, besides, outer, attached to)
genesis - “origin” (or coming into being of something)

preformation – new organism contained within sperm or egg
- no cell theory to constrain size
- age of Earth unknown
- eliminated need for “vital force”
- dispute between “ovists” and “spermists”

epigenesis – new organism formed de novo (“from scratch”)
- explained mixture of traits in hybrids
- explained blending of traits
- observations of embryos revealed structures unknown in adults
Germ Layers

germin – something that initiates development or serves as a an origin

ecto- outside, external

endo- inside, internal, within

meso- middle, intermediate

-derm skin, covering

blast – formative unit, especially of living matter, bud, budding, or germ

Ectoderm – outer layer; forms epidermis of skin, brain, CNS

Endoderm – inner layer; forms epithelium of digestive tract, associated organs

Mesoderm – middle layer; forms blood, heart, kidneys, gonads, bones, muscles, connective tissues

NOTE – triploblastic organisms (vertebrates, echinoderms, etc) have three germ layers; diploblasts (cnidaria, ctenophores, porifera) lack true mesoderm
von Baer’s Laws

1. General features of a large group of animals appear earlier in development than do the specialized features of a smaller group.

2. Less general characters develop from the more general, until finally the most specialized appear.

3. The embryos of a given species, instead of passing through the adult stages of lower animals, departs more and more from them.

4. Therefore, the early embryo of a higher animal is never like a lower animal, but only like its early embryo.
Experimental Embryology Techniques

**Isolation** – grow part of embryo by itself
- no communication, signals, regulation from the outside

**Removal** – portion of the embryo is removed; how does the remainder fare?

**Transplantation** – portion removed, then transplanted to -
- different place = *heterotopic*
- different age = *heterochronic*
- different species = *heterospecific*
- same species = *homospecific*

hetero – different
homo – same
topic – place
chronic - time
Transplantation

(A) Quail embryo 24 h Chick embryo 24 h

Quail cells

Chick embryo with region of quail cells on the neural tube

Radiolabeled donor

Host
Cell Lineage

*Ceanorhabditis elegans*

invariant cell lineages
959 cells; each lineage known
Fate Mapping Techniques

cell fate – what will a given cell eventually become?

dye marking

fluorescent marking

(A) Embryo

Agar chips with dye

cell movement during gastrulation
Fate Mapping Techniques

(A) Quail embryo vs Chick embryo

(B) Quail cells and Chick cells

Chick embryo with region of quail cells on the neural tube

genetic markers
Fate maps

early cleavage

zygote
Evolutionary Embryology

Homologies

Human arm
- Hand, wrist, and fingers
- Radius
- Ulna
- Humerus

Seal limb

Bird wing

Bat wing

Analogies?
Evolutionary Embryology

- Sea squirt (tunicate) (chordate)
  - Sea squirt larvae

- Barnacle (arthropod)
  - Barnacle larvae
  - Jointed legs, etc.

- Notochord, nerve cord
Evolutionary Developmental Biology

peripatus

distal-less

gene
Mathematical Embryology

(A)

Activator (P) stimulates production of inhibitor (S)

Rapidly diffusing inhibitor (S)

Autocatalysis

Slowly diffusing activator (P)

S diffuses quickly and inhibits autocatalysis of P

Time 1

Time 2
Mathematical Embryology

(B) Inhibitor (S)
Activator (P)

Time 1

Relative concentration

Time 2

Position

Time 3