Morphogenesis

Growth of nerve cells
Development of the brain

Roland Vogt

Gross Development

The earth was without form and void, and darkness was upon the face of the deep; and the Spirit of God was moving over the face of the waters.

1Mo 1,2

Gross Development

Morphogenesis

- 1st phase of live: development of the multicellular blastula

- Blastula contains 3 main types of cell lines:
  - Ectoderm: nervous system and outer skin, lens of the eye, inner ear, and hair
  - Mesoderm: skeletal system and muscle
  - Endoderm: gut and digestive organs

Gross Development

Morphogenesis

- 1st phase of development of the nervous system (neurulation):
  - Ectodermal cells of the on the dorsal surface of the embryo form the *neural plate*
  - Development continues with neural folds forming the *neural groove*
  - Cells of the neural fold region eventually meet and fuse, forming the *neural tube* that runs anteriorly and posteriorly along the embryo

Gross development

- 1st phase of devlopment of the brain
  - Neural tube has openings at both ends, called the anterior resp. posterior *neuropore*
  - Closing of the anterior neuropore forms the primitive brain consisting of 3 types of ventricles
  - The result is a cerebral cortex that envelops the cortical, subcortical and brainstem structures along the neural tube

Proliferation and migration of neurons

And God said, "Let there be a firmament in the midst of the waters, and let it separate the waters from the waters."

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1Mo 1,6

Neuronal Proliferation

Morphogenesis

- All neurons in the primate cortex are derived within 1 to 2 months during the middle third of gestation
- Neurons that form the cortex arise from a layer of cells located adjacent to the ventricles of the devolping brain, called the *ventricular zone*
- The ventricular zone contains undifferendiated *precursor cells* from which *neuron and glial cells* are produced

Neuronal Migration

Morphogenesis

- Radial glia cells are stretching from the ventricular zone to the surface of the developing cortex
- Neurons cells are moving along the radial glia cells to the surface of the cortex
- Neurons that migrate later are passing the earlier neurons and are ending up in more superficial position, i.e. nearer to the outer cortical surface

Determination and differentiation

And God said, "Let the waters under the heavens be gathered together into one place, and let the dry land appear." And it was so.

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1Mo 1,9

Determination

- First, the cells in the ventricular zone divide in a symmetrical fashion resulting in an exponential growth in the number precursor cells

- Then, asymmetrical division begins and one of the two cells present after division becomes a migratory cell

Determination

Morphogenesis

- Which type of neuron a migrating neuron will eventually become is determined at the point of cell division
- Once the neuron has been fated to migrate the cortical layer in which a neuron eventually will reside is determined

And God said, "Let the earth put forth vegetation, plants yielding seed, and fruit trees bearing fruit in which is their seed, each according to its kind, upon the earth." And it was so.

1Mo 1,11

Differentiation

Morphogenesis

- Neurons develop patterns of connectivity according to their target layer in the cortex
- Neurons take on the morphological form predicted by their age

The earth brought forth vegetation, plants yielding seed according to their own kinds, and trees bearing fruit in which is their seed, each according to its kind. And God saw that it was good.

1Mo 1,12

Differentiation

- There is strong evidence that the neuronal properties of cortical neurons are prespecified long before the migrating neuron reaches its final destination in the cortex
- In contrast, the neuronal properties of neurons in the peripheral sensory system are determined by the environment where they reside

Radial unit hypothesis

And God said, "Let there be lights in the firmament of the heavens to separate the day from the night; and let them be for signs and for seasons and for days and years,

1Mo 1,14

Radial unit hypothesis

Morphogenesis

- Radial glia cells form a pathway for neurons
- This radial glial highway is organized in a straight line from the ventricular zone to the cortical surface
- Therefore, there is a topographic relation between precursor cells in the ventricular zone and the coritcal neurons the yield in the adult

and let them be lights in the firmament of the heavens to give light upon the earth."
And it was so.

1Mo 1,15

Radial unit hypothesis

- Neurons „born“ next to each other in the ventricular zone end up next to each other in the cortex (and vice versa)

- The cortex shows a columnar organization which is derived during development of the brain

Radial unit hypothesis

Morphogenesis

- The cortical column is a principal unit of organization
- The brain has a modular and uniformly constructed architecture

Radial unit hypothesis

- The organization of the cortex in cortical columns has functional-anatomical consequences
- The intracortical interconnectivity among local neurons appears to be well suited to the size of cortical columns

Radial unit hypothesis

- Columnar development provides a method for the evolutionary expansion of cortical size
- Rather than enlarging each cortical unit, the number of units is increased

(Cyto-) Architectonic variation across cortical areas

And God said, "Let the waters bring forth swarms of living creatures, and let birds fly above the earth across the firmament of the heavens."

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1Mo 1,20

Protomap hypothesis

Morphogenesis

- Neurons located in the ventricular zone will establish a protomap that attracts the thalamic afferent fibers appropriate to the function that the region is destined to perform

- According to this view genetic factors predetermine the organization

So God created the great sea monsters and every living creature that moves, with which the waters swarm, according to their kinds, and every winged bird according to its kind. And God saw that it was good.

1Mo 1,21

Protomap hypothesis

Morphogenesis

- There is experimental evidence to support the protomap hypothesis
- The visual cortex can develop normal cellular makeup, intracortical synaptic organization, and neurotransmitter expression in the absence of activity from the retina

Influence of the environment

Morphogenesis

- The biochemical properties of neurons seems to be prespecified very early in the developmental process

- The extent to which these prespecifications reflect the final phenotype of the neurons can be influenced by the environment

1Mo “Genesis” Chapter 1

The holy Bible, Revised Standard version

Morphogenesis

24: And God said, "Let the earth bring forth living creatures according to their kinds: cattle and creeping things and beasts of the earth according to their kinds." And it was so.

25: And God made the beasts of the earth according to their kinds and the cattle according to their kinds, and everything that creeps upon the ground according to its kind. And God saw that it was good.

26: Then God said, "Let us make man in our image, after our likeness; and let them have dominion over the fish of the sea, and over the birds of the air, and over the cattle, and over all the earth, and over every creeping thing that creeps upon the earth.“

27: So God created man in his own image, in the image of God he created him; male and female he created them.

28: And God blessed them, and God said to them, "Be fruitful and multiply, and fill the earth and subdue it; and have dominion over the fish of the sea and over the birds of the air and over every living thing that moves upon the earth.“

29: And God said, "Behold, I have given you every plant yielding seed which is upon the face of all the earth, and every tree with seed in its fruit; you shall have them for food.

30: And to every beast of the earth, and to every bird of the air, and to everything that creeps on the earth, everything that has the breath of life, I have given every green plant for food." And it was so.

31: And God saw everything that he had made, and behold, it was very good. And there was evening and there was morning, a sixth day.