Chapter 9
Development of Ectodermal Organs

The ectoderm gives rise to 3 separate cell populations: neural(plate) ectoderm, neural crest cells, and epiderm (general body ectoderm). A **primordium (anlage)** is the first accumulation of embryonic cells which will become a structure.

9.1. Neural Ectoderm (Brain & Spinal Cord)

Recall, that as a result of tubulation, the neural plate forms a neural tube. The anterior region of the neural tube is expanded more than the posterior region (*larger diameter and thicker walls*). The anterior region will develop into the brain and the posterior region into the spinal cord.

(a) Development of the Brain

As a result of differential rates of mitosis the anterior neural tube develops three vesicles: **prosencephalon, mesencephalon and rhombencephalon**. The **prosencephalon** later gives rise to the **telencephalon** and **diencephalon**. The **mesencephalon** does not further subdivide. The **rhombencephalon** becomes the **metencephalon** and the **myelencephalon**.

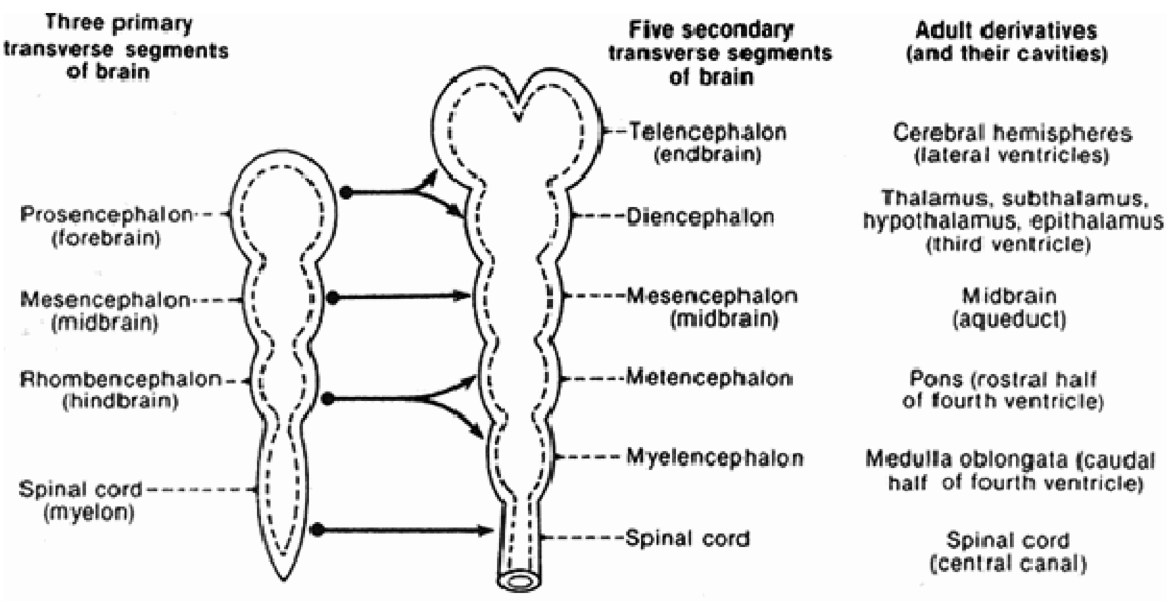

Fig.9.1. Development of the brain

In vertebrates with complex brains, the developing brain becomes flexed and folds upon itself, as a result of differential rates of mitosis. The telencephalon develops two lateral bulges which become the **cerebral hemispheres**. These are small in fishes, amphibians and some reptiles and larger in other vertebrates, being the largest in man. The cavities of the telencephalon become the **lateral ventricles**. The **olfactory bulbs**, which are especially prominent in lower vertebrates, develop as outgrowths of the telencephalon. The diencephalon develops a great variety of structures. The cavity of the diencephalon becomes the **3rd ventricle** of the brain.The infundibulum is a mid-ventral evagination which grows downward from the floor of the diencephalon. The **infundibulum** (from the diencephalon) joins with a **Rathke's pouch** (from the primitive mouth) to form the **pituitary gland** (**hypophysis**). The roof of the diencephalon (the **epithalamus**) becomes a **choroid plexus**, which brings O_2 and nutrients into the ventricles, while producing cerebro-spinal fluid from the blood.

The **pineal gland** forms from a dorsal evagination of the diencephalon. The **optic vesicles**, which are the rudiments of the eyes, appear as a pair of protrusions on the lateral walls of the diencephalon. The base of the optic vesicle becomes constricted forming the **optic stalk**, which later is transformed into the **optic nerve**. The optic vesicle grows outward until it contacts the epidermis. It then flattens and invaginates forming the double walled **optic cup**.The inner layer develops into the **sensory retina** and the outer layer into the **pigmented layer of the retina**. The rim of the optic cup becomes the **iris**. The cavity of the optic cup is the future **posterior cavity** of the eye.The optic vesicles induce the epidermis to develop **lens rudiments(placodes)** which develop into the **lens**.

The **chorioid coat** and **sclera** of the eye develop from mesenchyme around the eyeball. The **cornea** originates from both the epidermis and mesenchyme. The lens induces the formation of the cornea.

Neurons grow out from the retina and follow the optic stalk to the brain. Some of their axons cross to the opposite side of the brain, forming the **optic chiasma**, which is found in the floor of the diencephalon, just anterior to the infundibulum. The (midbrain) **mesencephalon** remains fairly simple in organization. The cavity of the mesencephalon becomes the **aqueduct of Sylvius (cerebral aqueduct)**. The dorsal walls of the mesencephalon form the **tectum**, which is an important nerve center concerned with vision and hearing. The **corpora quadrigemina** are four dorsal eminences of the midbrain. They serve as reflex centers for visual, auditory and tactile impulses.

The **cerebral peduncles** are the ventral part of the midbrain. They are made up of tracts that constitute the main connection between the cerebrum and the lower parts of the brain.

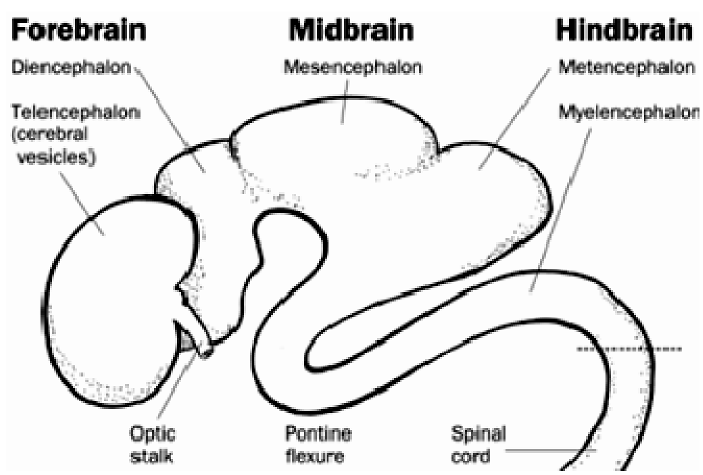

Fig.9.2. Structure of embryonic brain

The **rhombencephalon** further develops into the **metencephalon & myelencephalon**. The cavity of the rhombencephalon becomes the **fourth ventricle**. The **metencephalon** develops into the anterior portion of the **medulla oblongata**, the **pons** and the **cerebellum**, which functions in muscle coordination. The **myelencephalon** develops into the posterior part of the medulla oblongata. The ventral part of the rhombencephalon is made up largely of bundles of ascending & descending nerve fiber bundles (fasciculi). There are also numbers of **nuclei** (*groups of neuron cell bodies*) which give rise to some of the cranial nerves.

(b) The Spinal Cord

(i) Spinal Cord Anatomy

The **Gray matter** is in the shape of butterfly around the small **central canal**. The **White matter** surrounds the gray matter and consists of axons running up and down spinal cord in tracts. Dorsally, the **Dorsal median septum** extends almost to the central canal. Ventrally, the **Ventral median fissure** extends almost to the central canal. The gray matter is divided into 3 columns: The **Dorsal columns** consist of **interneurons** and axons from **sensory neurons**. The cell bodies of the sensory neurons are found in the **dorsal root ganglion** just outside the spinal cord. The **Lateral columns** contain cell bodies of **visceral motor neurons** which innervate the smooth muscles of the viscera. The axons of these neurons exit the spinal cord and pass through the ventral column and out into the ventral root. The **Ventral columns** contain the cell bodies of the **somatic motor neurons** which innervate the striated muscles of the body. Their axons pass out of the spinal cord into the ventral root.

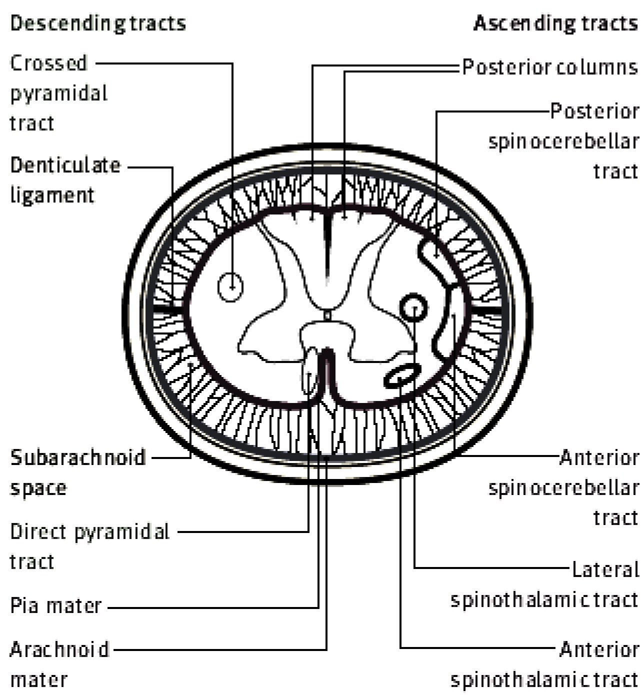

Fig.9.3.CS of the spinal Cord

(ii) The Development of the Spinal Cord from the Neural Tube

The central canal of the neural tube is lined with a layer of **neuroepithelium**. This is single layer of pseudostratified columnar neural epithelium, with each cell attached to the basement membrane at the center of the neural tube. The neuroepithelial cells behave as rapidly dividing stem cells. Differential rates of cell division cause some areas of the brain and spinal cord to become larger than other areas.

Some of the neuroepithelial cells give rise to the **ependyma**, which is the simple cuboidal lining of central canal and brain ventricles. They also form the **epithelium of choroid plexuses**, which produces cerebrospinal fluid. Some of the neuroepithelial cells migrate outside of the neuroepithelium and give rise to **neuroblasts**, which differentiate into **neurons**. This region is the **mantle** and will become the **gray matter**. Other neuroepithelial cells migrate to the mantle and form **glioblasts**, which give rise to **astrocytes** and **oligodendroglial cells** (which are also derived from neural crest cells). Astrocytes associate with capillaries to form the **blood-brain barrier**.

Oligodendroglial cells from **myelin sheaths** around some axons. **Mesenchyme cells** also migrate into **mantle** and form **microglial cells**, which can become phagocytic in regions of damage or inflammation. Outside the mantle is the **marginal layer,** which becomes the **white matter.** It consists of processes (axons and dendrites) from the developing neurons and also **neuroglia** *(supportive non-nervous cells of the nervous system)*. The glial cells produce myelin membranes which give the marginal layer its glistening white appearance.

The ventral tissue of the neural tube grows downward leaving a narrow slit, the **ventral median fissure**. Dorsally the central canal becomes compressed. The dorsal walls of the central canal fuse to form the **dorsal median septum**. Therefore, only the ventral part of the central canal remains, as a small round **central canal**.

Even before the dorsal part of the central canal compresses and closes, a pair of lateral grooves appear in the lateral walls of the neural tube. These are the **limiting grooves (sulcus limitans)** and they divide the lateral walls of the neural tube into an upper **alar (dorsolateral plate)** and a lower **basal (ventrolateral plate)**. The dorsolateral plate will contain sensory neurons and therefore will form the dorsal columns. The ventrolateral plate contains motor neurons and therefore will form the lateral and ventral columns. Thus, the limiting groove **divides** the **sensory** neurons & the **motor** neurons.

9.2. The Fate of the Neural Crest Cells

(a) The Origin of the Neural Crest

As the neural plate and epidermis close to form tubes the neural crest cells come to lie between the neural tube and the epidermis. The neural crest cells (which are ectodermal) then migrate in streams to various parts of the embryo and form various structures. Some of the structures formed by the neural crest cells are as follows:

Chromatophores, which are pigment cells. Most of the visceral skeleton (i.e. visceral arches). Oddly, the 2nd basibranchial in amphibians is mesodermal, as is the vertebral column and appendicular skeleton.The papillae of teeth, at least in urodeles. The papilla is the connective tissue part of a tooth rudiment and will later form the dentine. Ganglia of the Autonomic Nervous System. Some cranial nerve ganglia are in part made from neural crest cells. Schwann cells, which form the myelin sheaths of some nerves. Meninges (at least the pia mater and arachnoidea) Subcutaneous connective tissue is partly neural crest & partly mesenchyme.

Spinal ganglia

(b) Development of Spinal Nerves and Ganglia

Some of the neural crest cells migrate down the sides of the neural tube. Here they form small masses of cells at regular intervals along the neural tube. These are the rudiments of the dorsal root ganglia. The cells of these rudiments then send out processes (axons) in two directions:

1. Toward the periphery, where they will synapse on sensory receptors in skin, muscles and visceral organs and
2. Toward the dorsal neural tube, where they synapse on cell bodies of the mantle layer.

These neurons, which have their cell bodies in the dorsal root ganglia, are sensory neurons; they carry impulses from receptors to the spinal cord. The processes of these neurons make up the dorsal root. The ventral root is made up of axons from the motor neurons, which have their cell bodies in the ventral and lateral columns. These axons grow out and innervate muscles and glands.

9.3. The Attraction of Nerves by the Developing Peripheral Organs

If a limb bud is removed from one side of an embryo, then that side of the spinal cord will degenerate to some extent and will be smaller than the intact side of the embryo. Conversely, if an extra limb bud is implanted on one side of an embryo, then that side of the spinal cord will be larger than the unoperated side. Therefore, the peripheral organs may influence the development of the central nervous system. If an obstacle (like a piece of mica) is placed between the spinal cord and the developing limb rudiment, the nerves will grow around the obstacle and innervate the limb. If the limb rudiment is transplanted a short distance from its normal location, the nerves will deviate from their normal paths and innervate the limb. However, if the limb rudiment is transplanted too far from its original location nerves from **that** region of the spinal cord will innervate it, but movement of the limb is not normal. If a limb rudiment is replaced by an eye rudiment, nerves will be attracted to the eye rudiment, but will not connect with it. It may be that fibers are predetermined to hook up with particular muscles or organs. The mechanism of nerve extension to peripheral organs has been shown, not to be chemical, electrical or magnetic.

It is controlled by the ultramicroscopic structure of the colloidal **extracellular matrix**, which is what the tip of the neuron moves through. Apparently, cues in the extracellular environment establish pathways for the axon extensions. Some cues are non-specific. Nerves from other levels grafted to the site of the hind limb will follow the system that the appropriate nerves would have. Other cues seem to sort out the axons and to direct innervation at specific muscles and organs. The nerves are not usually necessary for the development of the peripheral organs. But without innervation the tissues degenerate.

9.4. The Fate of Epidermis

Most of the epidermis of the embryo becomes the epidermis of the skin, which overlies the dermis (which is derived from the mesoderm). The epidermis gives rise to skin glands, hair, feathers, scales, *etc*. The epidermis also gives rise to some organs. These first appear as plate-shaped thickenings in the skin called, **placodes**. Organs which form from epidermal placodes are ganglia of some cranial nerves, lens rudiment, which form the lens and the olfactory sacs, which form the nasal sensory organs. The auditory placode, which forms the ear vesicle, which is the rudiment of the internal ear and the lateral line sense organs of fish