Module:
Biological foundations of mental health

Week 1
Introduction to brain anatomy

Topic 1
Overview of CNS development – Part 1 of 3

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Lecture transcript

Slide 2
Neural Development.

We can think of neural development as taking place on two levels, namely, a 'systems' level and a cellular level. In this topic, we will first consider the systems level, looking at the changes in size and shape that occur during the embryonic development of the nervous system. This process is called morphogenesis.

Next, we will describe changes at the cellular level that allow cells to change from dividing progenitors into mature neurons with complex morphologies, interconnected in circuits. This process is called differentiation. In the final section we will show the relevance of each stage of neural development to mental health by outlining the disorders that can result from defects that arise in specific developmental events, with examples.

Slide 3
Levels of Neural Development.

In humans, development begins with fertilisation of the egg, which cleaves to give rise to a ball of cells called a blastocyst. Implantation of the embryo into the uterine wall occurs at the end of the first week. And further development generates a two-layered embryonic disc, consisting of hypoblast and an epiblast. At the end of the second week, the process of gastrulation transforms this disc into a three-layered structure consisting of three so-called 'germ' layers-- the ectoderm, mesoderm, and endoderm-- which give rise to all the tissues of the body.

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By the end of the third week, the process of neurulation begins, which creates the embryonic nervous system. Amazingly, in weeks 4-5, the embryo starts to be recognisable, with a head, tail, and some of the embryonic structures that will be present in the adult, such as the limb buds, which grow into the limbs. This stage is often called the 'tailbud' stage.

In humans, the second month of gestation is referred to as the embryonic period, during which the major organ systems start to form. And months three to nine is the foetal period, which is mainly concerned with growth. Large amounts of cell proliferation take place, a process which is particularly important for the brain.

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Further development of the nervous system involves the ectoderm, which develops under the

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influence of signals from the underlying mesoderm, a process called neural induction. During this process, a portion of the ectodermal germ layer is induced to become neural tissue, which will form the nervous system. As the tissue becomes neural, it also undergoes morphogenetic changes in shape, called neurulation.

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We will now look at neurulation in more detail, visualising the process of neurulation in a surface view, a transverse view, and in scanning electron micrographs of a human embryo.

Early neurulation, at three weeks. The surface view is shown with the anterior, or cranial, end of the embryo at the top of the picture and the posterior, or caudal, end at the bottom of the picture. The arrow shows the level of the surface view at which the transverse section is taken. In the transverse section, at 19 and 20 days, we can see that the embryo consists of three germ layers.

The ectoderm lies on top, and the medial part will give rise to the nervous system, with the more lateral regions giving rise to the epidermis of the skin. The medial part forms the neural plate, which has started to thicken. Underneath it lies the mesoderm, consisting of the notochord, medially, and two other blocks of mesoderm, laterally. Underneath this lies the endoderm.

We can see that between 19 and 20 days, the neural folds rise up on either side of the midline and form a v-shape. Somites form from some of the mesoderm underneath these folds, which will later form the axial muscles. In the surface view, the somites can also be seen to form small blocks of tissue, and the embryonic disc to lengthen further. In the surface view, we can see how the neural folds form first at one axial level.

In the scanning electron micrograph of the human embryo, the neural tube looks somewhat striated because of the somite blocks beneath it.

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During later neurulation, at 22 to 23 days, looking first at the transverse section, the neural folds can be seen to approach each other, and the somites to have expanded. Eventually, the neural tube closes and becomes enclosed and separated from the layer of ectoderm which forms over the top.

In the surface view, it is clear that one region of the neural tube has started to fuse. This is typically the neck region. At the later stage we can see that the neural tube starts to zip up, towards the anterior and the posterior ends, and the nervous system starts to be subdivided, with the spinal cord posteriorly, and the brain vesicles, or subdivisions, more anteriorly.

The scanning electron micrograph of the human embryo is very similar to the diagram, but the embryo is attached to extra embryonic membranes which will later cover it.

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By the tailbud stage, which is at four to five weeks of gestation, cranial and caudal folding has occurred, arching the body to give it what has sometimes been referred to as a 'comma' shape.

Lateral folding has also occurred to enclose all forming internal organs in a covering of ectoderm, which will become the skin. We can see that the embryo has acquired a more recognisable appearance, with a head and tail somite blocks, and structures called branchial, or pharyngeal, arches, which will form elements of the lower jaw and neck.

At a later stage of human development shown, you can also see the limb buds, outpocketings of tissue which will eventually grow into the limbs. The diagram highlights the developing eye, and the otic vesicle, which will give rise to the inner ear. In this way, the major structures of the developing embryo are already formed by four to five weeks.

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Surprisingly, the embryo of a human looks extremely similar to that of other animal groups at this stage. These beautiful drawings by the 19th century embryologist, Haeckel, show that at the tailbud stage, all the essential features of the body plan are present and look similar, even though the eventual body plan of these different organisms is rather different.

Haeckel may have exaggerated the similarities somewhat, for effect, but the basic idea is correct. This also brings home the point of why we can study a variety of different experimental organisms in order to understand more about human development.

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Looking now at the further development of the neural tube without the other tissues, we can see that the cranial to caudal folding of the tube has taken place in concert with the folding of the rest of the embryo. Several subdivisions now appear in the tube. Whereas the region of the developing spinal cord remains with a small diameter, the forebrain, midbrain, and hindbrain, also termed the prosencephalon, mesencephalon, and rhombencephalon, have started to expand.

The prosencephalon is divided into the telencephalon more cranially, and the diencephalon more caudally. The telencephalon is later destined to give rise to most of the cerebral hemispheres via an extensive folding process. The diencephalon will give rise to some of the important collections of neurons, such as the thalamus. These sorts of collections of neurons are termed nuclei.

The folding of the neural tube which occurs involves the formation of flexures. In this way, convex flexures at the midbrain, and at the level of the junction between the spinal cord and the hindbrain, create the more mature morphology. A third, concave flexure also appears in the hindbrain, which means that the cranial part of the hindbrain, called the pons, becomes separated from the more caudal region, the medulla.