Module:
Biological foundations of mental health

Week 1
Introduction to brain anatomy

Topic 2
Neuroanatomy, neural systems and brain function – Part 2 of 3

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Lecture transcript

Slide 2
Now, let's think about dividing the nervous system up anatomically. The problem here, before we start, is to make sure you understand the axes and planes involved. This isn't as straightforward as it might sound, and it arises because of our evolutionary change from fish and quadrupeds to bipeds.

For a fish or a mouse, for example, it's very simple. The part coming towards you is the anterior end, and the part furthest away is the posterior. As soon as we stand up, we have a problem because the part coming toward you now is the anterior end, but also it's the belly, and the part furthest away is the posterior end, but it's also the back.

Before, these were orthogonally arranged. So we have anterior and posterior is not the same as the belly and the back. So what you will come across a lot in topographical anatomy generally, but neuroanatomy in this context, is the terms 'ventral' and 'anterior' on the one hand, and 'dorsal' and 'posterior' on the other, become synonymous. I'll be using them interchangeably throughout the course of this lecture, and you will find in textbooks and reference papers them also being used interchangeably.

There is one other degree of complexity that's introduced, in terms of axes and plane terminology as far as the nervous system is concerned, and this is because of something called cranial flexion. What this means is the long axis of the spinal cord is approximately at right angles to the long axis of the brain. And this occurs during embryological development.

So what this means is, if we are describing the front of the spinal cord, we can refer to it, for example, as the ventral surface. This would be this surface of the spinal cord. But because of cranial flexion, the ventral surface of the brain now becomes the underside of the brain. Similarly, the dorsal surface of the spinal cord is continuous with the dorsal surface, which now is the top, the superior surface of the brain.

So pay attention to these terms, because it might not be immediately obvious. If people are talking about the dorsal aspects of the brain, they're really talking about the top, and if they're talking about the ventral surface of the brain, they're really talking about the inferior, lower surface because of this cervical flexion, or cranial flexion, that occurs during development.

And lastly, be familiar with the main three planes that are used to describe sections through the brain: horizontal, which is effectively transverse sections; sagittal, which runs through the midline, from Sagittarius the archer, the stance an archer would take; and coronal, or a frontal, section, parallel with the plane of the face. Corona is Latin for a crown. So it's imagining putting a crown on your head.

So these terms will be used a lot in the lectures that you'll be coming across. So do pay attention to what they mean - sagittal, horizontal, and coronal, the three main planes to divide up the brain. Now with this in mind, we can start looking at the anatomical divisions of the brain in a little more detail.

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So this is the commonest way to anatomically divide the brain, into four main parts: the spinal cord, which ends approximately at the level of the foramen magnum, the large hole in the base of the skull; which is then continuous with the hindbrain, which is made up of these three parts we'll meet in a little bit more detail later, the medulla, the cerebellum, and the pons; and above that, this region called the midbrain; and above this, the much bigger area, which represents the cerebral hemispheres of the forebrain. And we'll be looking briefly at each of these.

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Let's start with the spinal cord. These should be familiar to most of you already, so I don't want to say too much about this. It's just to remind you of two things, really.

The first is the white matter, composed of axons, is largely on the outside of the spinal cord. This is the opposite arrangement to the brain, where on the outside, it's mainly the grey matter, which is the cell bodies. The grey matter in the spinal cord sits in the middle. The exact shape will change according to where you are in the spinal cord. But it's roughly the shape of the letter 'H' no matter where you are.

The other thing to note is that the nerves associated with the spinal cord are mixed. So this nerve that's going out to the periphery will have both sensory neurons within it, they're bringing information in with cell bodies in the dorsal root ganglia, projecting their information into the cord, as well as axons projecting their information out to skeletal muscle.

So each of the spinal nerves is mixed - has both sensory and motor information. They enter and leave the cord as a series of rootlets, multiple entry and exit points for each spinal nerve.

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We have 31 spinal nerves, most individuals do. A few exceptions, where some have one or more, one fewer or one more. But the vast majority of people have 31, of which there are 8 cervical, 12 thoracic, 5 lumbar, 5 sacral. And if there's any variation, it comes in the coccygeal nerves, but most of us only have one. They exit through holes - foramina - between the vertebra, the intervertebral foramina.

Now the spinal cord isn't as big as the vertebral column. In fact, it's only about 2/3 of the length of the vertebral column. It stops growing at the same rate by about the end of the first trimester. After that, the vertebral column is growing faster.

Now that has important consequences, some of which are exploited clinically. What this means is that the spinal cord is ending at about the level of the intervertebral disc between L1 and L2. But because each spinal nerve exits through a corresponding intervertebral foramen, it means that any nerve below L1 and L2 has to travel down the spinal cord until it finds its corresponding intervertebral foramen and exits.

S1, for example, segment S1 of the spinal cord is here, but the first sacral vertebra is here. So this nerve has to project down through a space below the level of the cord before it exits. This means that you have a group of nerves at the base of the spinal cord where there's no neural tissue, no cell bodies involved. This gives the name to this structure, the cauda equina, the horse's tail, because that's exactly how it appears in a fresh specimen.

And clinically this is important, because it means a needle can be put into the spinal cord below the

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level of L1, L2 - for example, to drain cerebrospinal fluid diagnostically, or if build up of pressure - knowing that you're going below the level of the spinal cord itself and therefore won't damage it. And this, of course, is done in lumbar punctures.

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Let's move up a little higher. The spinal cord, as I mentioned, ends at the intervertebral foramen, and above that, we come to the region of the hindbrain, the medulla, the cerebellum, and the pons.

The medulla is the oldest part of the hindbrain in evolutionary terms, and in fact, it's the oldest part of the brain in all. It contains life-supporting centres - this is the part of the brain that keeps you alive on a minute-to-minute basis.

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Above the hindbrain is a relatively smaller area, the midbrain, separated by a small channel. Small, but an important area of the brain. Amongst other things, it's a very important relay between activity in the forebrain above and the hindbrain below.

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Sitting on top of the midbrain is a structure called the thalamus, and we'll meet this again later. This is a part of the brain called the diencephalon, And it's a very important relay. Virtually all sensory information, whether it's special sensory, such as taste or vision or hearing, go through the thalamus. Or somatosensation, fine touch, coarse touch, vibration, pain, temperature, go through the thalamus. And it's also, as we'll see, an important relay for descending information, motor information as well.

You will find that there are some texts that include the thalamus in the brain stem, and there are evolutionary reasons why you might do so. There's functional reasons why you might do so. But in general, in the UK, we tend to regard the thalamus as a separate structure to the rest of the brain stem. In American texts, the tendency is to include it with the brainstem.

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Let's think about the brainstem. That area shown in red on the rotating skull here is the most important part of the brain. It's the reason why brainstem activity is used as a clinical descriptor of life. I'm sure you've heard of the term 'brainstem death', which is used to clinically define whether somebody is capable of independent life or not.

And it's complicated because there's a lot going on. There are ascending, somatosensory, and descending motor pathways going through it. Also, there are lateral connections between the stem of the brainstem and the cerebellum dorsal to it. A lot of the cranial nerve nuclei-- remember you have 12 pairs of cranial nerve nuclei-- most of those are contained within it. it's an important centre for chemo reception, as well as a number of cranial reflexes, such as salivation, mastication, swallowing. We could also include the gag reflex and suckling in infants amongst these.

It's important for a number of vital life-supporting roles, which we've already mentioned the cardiovascular and respiratory ones sitting in the medulla. But there are others as well, not least those concerned in arousal - arousal as wakefulness, keeping you out of a comatose state. All of these are important activities of the reticular formation, which runs throughout the brainstem.

Finally, there are three important nuclear groups: the raphe, the locus coeruleus, and the substantia nigra, which also reside in the brainstem. These are the sites of very important monoaminergic pathways within the brain.

The raphe, for example, is the centre for all the serotonergic pathways within the brain. If you use serotonin as your neurotransmitter, they originate from a site within the brainstem.

The locus coeruleus is the site of all the adrenergic pathways - pathways that use adrenaline, noradrenaline, as the neurotransmitter, originates from the locus coeruleus.

And the substantia nigra is the important centre for dopaminergic neurons within the brain, very important in movement control. Parkinson's disease is the loss of the dopaminergic neurons from one part of the substantia nigra. So the brainstem is responsible for a very large range of important functions to keep us alive.

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If we move up to the forebrain, the first thing you notice is that it's large and thrown into a large number of folds. The folds increase the surface area of the brain, so we can fit more neuronal tissue into the cranium, and the ridges are known as a gyrus. This, for example, is the middle temporal gyrus, plural gyri. And the grooves, here we have the central sulcus, plural sulci. There are bigger divisions too. Here, for example, is the lateral fissure. Separating the cerebellum from the cerebrum, we have a transverse, or horizontal, fissure.

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Now we can divide the brain up into lobes, as I'm sure you know, and the lobes are named after the associated bone of the cranium.

So normally, the brain is described as having four lobes, an occipital lobe, parietal lobe, frontal lobe, and temporal lobe. You may also see some texts that include a limbic lobe, which is a part of the brain concerned with determining your emotional state, and that's buried deep within the brain. But that's less common. It's much more common to refer to these four.

What's important to note here is that no single function of the body is concerned with any one lobe. So if we look at the frontal lobe here, for example, this has many functions. But one of the main ones is movement, since much of the motor cortex resides within the frontal lobe.

But for effective movement control, you also need the activity of other lobes. For example, the parietal lobe is very important in receiving feedback from the rest of the body, or the skeletal musculature of the body, to perform effective motor functions. So motor functions can be regarded as spread over both of these lobes.

Similarly, the parietal lobe has important roles in determining your interpretation of what you see. So that indicates that the parietal lobe has multiple functions. The occipital lobe also is important in vision, houses the primary visual cortex. So the take-home message here is that you cannot allocate a single function to any one lobe, and no one lobe has just one function.

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When we look at the outside of the brain, we're looking at the cortex, the outer layer. But there's more to the cerebral hemispheres than the cortex. Buried deep within it are other structures, and we refer to groups of cell bodies within the nervous system as nuclei.

Now this has nothing to do with the term used to house your genetic material within a cell. In neuroanatomy, a nucleus is just a group of cell bodies of similar function, and buried deep within the cerebral cortex, we have a number of nuclei.

Some here, for example, are nuclei of the basal ganglia, a very important group of cells involved in movement control. There are also various small nuclei dotted around that aren't shown on this figure, but also associated with the basal ganglia and other parts of the brain.

In particular, the one that's not shown here is the hippocampus. That would be sitting deep in the temporal lobe. We can't really see that. That's an important nucleus, concerned, amongst other things, with memory.

In addition to these nuclei, at the top of the brain stem is the diencephalon, a group of nuclei of great range of functions. This one you've met already. This is the thalamus. I mentioned that that was important for motor and sensory relay.

Below it is the hypothalamus, under the thalamus. The hypothalamus, an important structure, amongst other things, concerned with autonomic control such as reproductive behaviour, thirst, measuring glucose levels, a number of other important homeostatic functions.