

Chapter H: Central Nervous System

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Peripheral Nervous System

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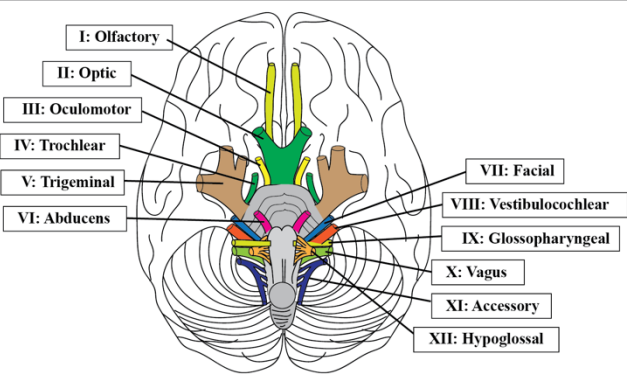
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H.5. Somatic Nervous System

A. Introduction:

1. In the previous sections/chapters, we discussed at length the major parts of the Central Nervous System (CNS).	2. It is now time to start discussing the other part of the nervous system; the Peripheral Nervous System.
3. What is the major difference between the Central and the Peripheral nervous system? The peripheral system is located outside the skull and the vertebrae; is therefore not protected by the bony structures.	3. The Peripheral Nervous System consists of two major parts: a. the Somatic Nervous System b. the Autonomic Nervous System
4. In this section (H.5.), we will discuss the Somatic Nervous System and in H.6. the Autonomic Nervous System (ANS).	

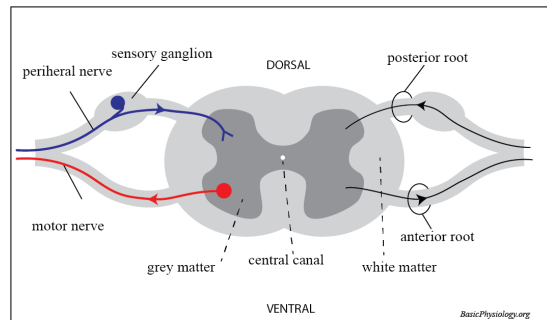
B. Somatic Nerves:

1. The somatic nervous system consists (again!) of two parts; afferent motor nerves that run to effectors (muscles, glands etc.) and efferent sensory nerves (such as taste and touch) to the CNS.	2. All these nerves can be grouped into nerve bundles. In the upper part of the body, these nerves run through the 12 cranial nerves (I-XII). <i>See H.2.2. Cranial Nerves</i>
3. The first two cranial nerves (olfactory and optic nerve) are actually part of the CNS as they are located inside the skull but that is a minor issue.	4. The other 10 cranial nerves (III-XII) originate from the brainstem and are mostly involved in the function of organs (muscles etc.) located in the head.
 BasicPhysiology.org	

5.

For the rest of the body, the spinal nerves are responsible for the somatosensory network.

These spinal nerves come out of the spinal cord in the space between two adjoining vertebrae, towards and from the left and the right side of the body.



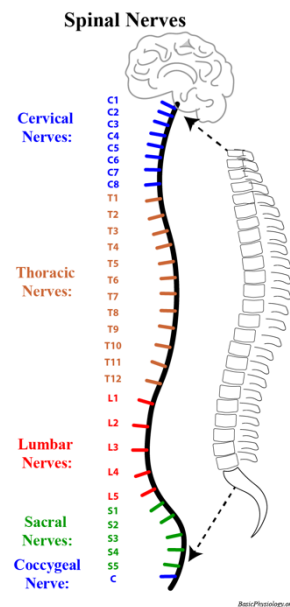
6.

In humans, there are 31 pairs of spinal nerves:

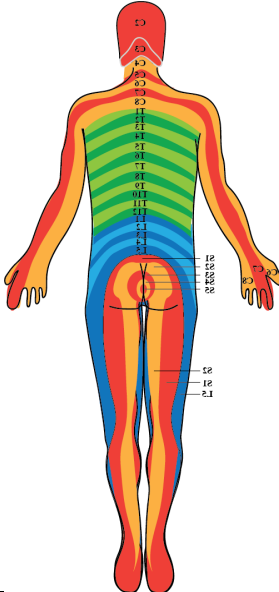
- a. 8 cervical
- b. 12 thoracic
- c. 5 lumbar
- d. 5 sacral
- e. 1 coccygeal

7.

The last one, the coccygeal (= tailbone; remnant of 'our' tail) nerve is often forgotten! Even I forgot it (*see H.3.2 Sensory pathways*).



C. Remember the dermatomes?

1. As we said before, the sensory nerves come for a large part from sensors located in the skin (touch, temperature and pain). These afferent nerves run to the nearest nerve bundle to enter the spinal cord and the brain.	
2. The origin of these nerves and their sensors can therefore be grouped together into 'dermatomes', as discussed in H.3.2. <i>Sensory Pathways.</i>	
3. More or less the same also applies to the efferent nerves; the nerves that run from the spinal cord to their effectors (muscles, glands etc.). However, these effectors are located inside the body, coupled to the skeleton and other organs and therefore not 'visible' on the surface of the body as are the sensors.	4. In fact, the efferent nerves can be better described in anatomical then in physiological terms.

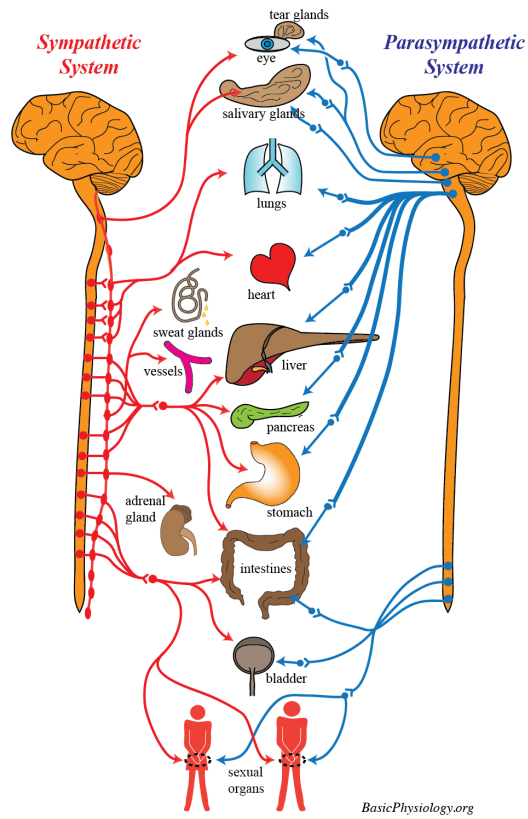
D. Nerves and Muscle groups in the Human Body:

Neck area: The Phrenic nerve: from C3 and C4 and runs straight through the thorax to the diaphragm. It is a major nerve for our respiration!	
Shoulder: The muscles on and around the shoulder and the upper part of the thorax are innervated by:	N. Thoracicus longus -> M. Serratus anterior N. Thoracodorsalis -> M. latissimus dorsi N. Pectoralis medialis and lateralis -> the major and minor pectoralis muscles N. Axillaris -> M. deltoideus N. Dorsalis scapulae etc. -> shoulder muscles

Arm: All the nerves for the arm originate in the brachial plexus (C1 – C8):	N. Musculocutaneus -> M. biceps, M. brachialis etc.) N. Medianus -> many muscles in the lower arm and hand N. Ulnaris -> many muscles in the hand N. Radialis -> many muscles in upper and lower arm
Thorax and Abdominal wall: these nerves originate from Th1 up to Th12.	N. Intercostales -> innervate the muscles of the ribcage (Breathing!) and also the muscles in the abdominal wall (M. rectus abdominis etc.)
Hip and Pelvis: these nerves originate from the plexus lumbosacralis (from L1-L5 and S1 to S4)	M. psoas major, minor N. ilioinguinalis and N. genitofemoralis innervate the skin (sensory) and muscles (motor) of the external genitalia of both males and females N. Gluteus superior and Inferior innervate the gluteus muscles in the hip (M. gluteus maximus etc.)
Leg: these nerves also originate from the plexus lumbosacralis	N. Obturatorius innervate several adductor muscles in the legs N. Femoralis innervate the muscles that stretch our legs (M. quadriceps femoris and M. sartorius) N. Ischiadicus innervate the dorsal muscles and also divides into two other nerves: a. N. Peroneus and N. Tibialis who also innervate many muscles in different parts of the legs.

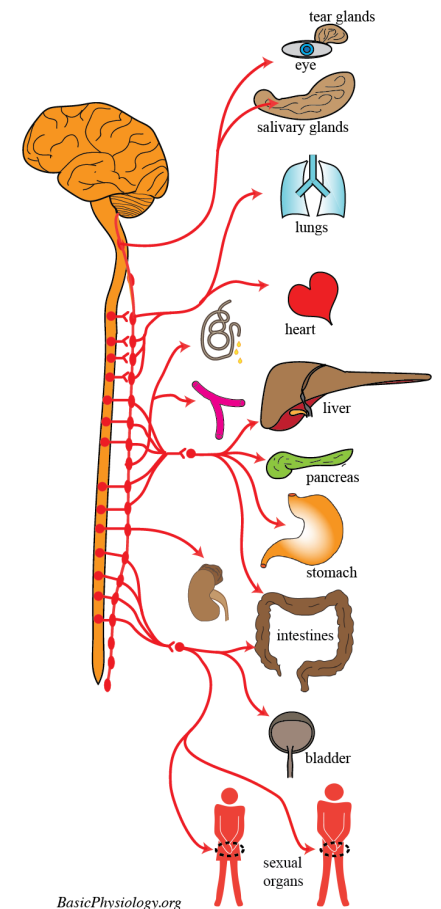
H.6. Autonomic Nervous System

A. Introduction:

1. Autonomic Nervous System!! This is a nervous system that is autonomic; that is; independent (to a certain degree) of the CNS.	2. It is like having a robot inside your body that controls things that you have no idea about!
3. I am not exaggerating. This part of the nervous system is very busy controlling many things in our body.	4. As you can see in the diagram, the autonomic nerves are projecting into an immense number of internal organs, from the heart and the lungs, to the intestines, all kind of glands, etc.
5. The autonomic nervous system, is also called the vegetative system or the involuntary system.	 The diagram illustrates the autonomic nervous system (ANS) pathways. It shows the brain at the top, with red lines representing the Sympathetic System and blue lines representing the Parasympathetic System. The Sympathetic System originates from the thoracic and lumbar regions of the spinal cord, while the Parasympathetic System originates from the brainstem and sacral regions. Various internal organs are shown, including the eye, tear glands, salivary glands, lungs, heart, liver, pancreas, stomach, intestines, bladder, and sexual organs. Arrows indicate the direction of nerve impulses from the CNS to these organs. The diagram also shows the adrenal gland and sweat glands. At the bottom, two human figures are shown with red and blue lines indicating the distribution of these systems throughout the body. The source 'BasicPhysiology.org' is noted at the bottom right of the diagram.
6. It involves 'controlling' five different intestinal systems:	
1. the Circulatory system 2. the Respiratory system 3. the Digestive system 4. the Urinary and Genital system 5. the Skin	
7. Not only must all these systems be 'regulated', but they must also be coordinated and work together.	
8. For example, it is pointless to force the heart to pump harder and the lungs to decrease breathing at the same time; that would contradict each other. Of course, that shouldn't happen!	

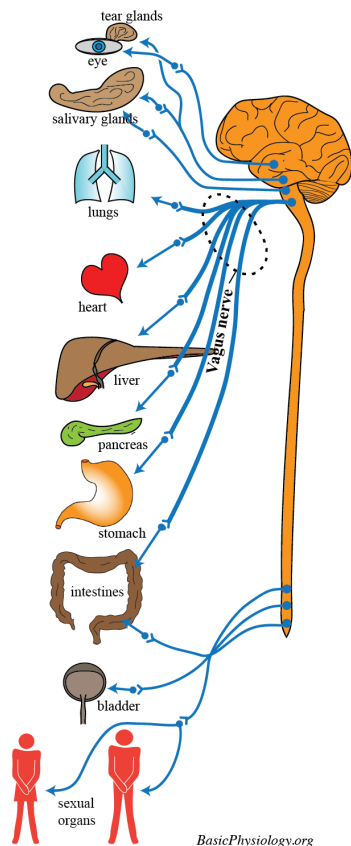
9. The autonomic nervous system consists of two systems that are each other's opposite: a) The Sympathetic System b) The Parasympathetic System	10. All the internal organs are controlled by both systems whereby the sympathetic usually ' <i>excites</i> ' the organ while the parasympathetic system ' <i>inhibits</i> ' these organs.
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B. The Sympathetic System:

1. The sympathetic system starts with several nuclei, located in the hypothalamus, the medulla oblongata, and the spinal cord.	 BasicPhysiology.org
2. As you can see in the diagram, the nerves from these centers leave the Central Nervous system into a string of nuclei, many of them located as a 'string' running parallel to the spinal cord.	
3. In these nuclei, the nerves connect through a synapse to a second nerve that connects to the intestinal organs.	
4. It is actually quite a complicated network of nuclei and synapses, that must be very interesting for neurophysiologist. But for us, basic students, the important thing to remember is that the sympathetic nerves runs from the central nervous system, to all the internal organs in the body; that's enough!	
5. What is much more interesting and relevant is what does the sympathetic system do? In one word: WORK!	
6. The sympathetic system excites (= stimulates) the internal organs. This is necessary when the body is going to exercise, strong emotions, harder working, fear, or anger!	

7. In those situations, more energy is required for muscles to work harder, so the lungs and the heart must work harder and/or stronger to pump more oxygen to these muscles, and more sugar and adrenaline is also required for this to happen.	8. But, at the same time, the work of some other internal organs simultaneously be decreased. For example, the stomach and the intestine must work less or else they would interfere with the harder work that the heart and the lungs have to perform.
9. So, there is a delicate balance between those internal organs that are working harder while other organs work less.	10. You can also see that in the behavior of the blood vessels. During the sympathetic drive, the blood vessels to the skeletal muscles will dilate (to transport more oxygen and nutrients to the muscles), while the blood vessels to the intestines will constrict. Perfect balance!

C. The Parasympathetic System:

1. As you can now understand, the parasympathetic system is the opposite of the sympathetic system!	 The diagram illustrates the parasympathetic nervous system's distribution. A central brainstem is shown with blue lines representing the vagus nerve extending downwards. Branches of this nerve connect to various organs: tear glands, eye, salivary glands, lungs, heart, liver, pancreas, stomach, intestines, bladder, and sexual organs. The organs are depicted in a vertical column on the left side of the diagram. The vagus nerve is labeled 'Vagus nerve' in blue text. At the bottom, two red human figures are shown, representing the overall system's effect on the body.
2. Instead of activating or stimulating our body, the parasympathetic system calms it down!	
3. The parasympathetic system decreases the heart rate and contraction, lowers the breathing of our lungs, narrows the blood circulation to the skeletal muscles, etc.	
4. And, again, as the opposite of the sympathetic system, it also activates some internal organs that are useful in restoring and keeping our body healthy, by stimulating the intestines, dilating the relevant blood vessels, storing energy in our cells, so that we are again prepared for another sympathetic 'attack'!	

5. There is one more important thing to remember in the parasympathetic system, and that is the presence of the most important nerve in our body; the vagus nerve.	6. As you can see in the diagram, in contrast to the innervation of the sympathetic system, most of the parasympathetic nerves run through one 'huge' nerve, the vagus nerve.
7. Only high in the brain and the upper part of the spinal cord, and in the most distal part of the spinal cord, do other parasympathetic nerves connect to their respective organs.	8. But the vast majority of the internal organs are parasympathetically connected through the vagus nerve. Remember!

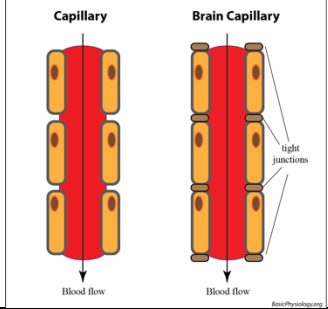
H.7. Blood Circulation and Glymphatic System

B. Introduction:

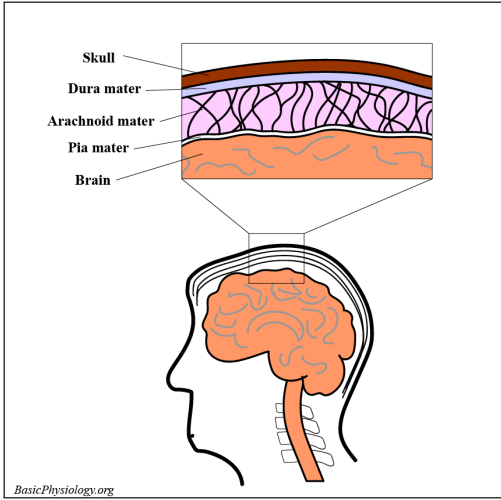
1. There are many special things about the CNS (as you have seen in previous pages) but there is one more to go! The blood circulation and the lymph circulation.	2. The blood circulation is of course crucial to our well-being and because our brains are so 'delicate', they need extra protection, even from the circulating blood!
3. And, then, there is another surprise; there are NO lymphatic vessels in the CNS!	4. That is weird! Isn't the lymphatic system designed to remove waste products from the external fluid?
5. Yes, that is true, but this is so crucial that another system has developed in the CNS; the glymphatic system; which we will (also) describe in this page.	

C. Blood circulation:

1. As in other organs, the capillaries in the CNS are responsible for the transport of fluid and many molecules from the blood to the interstitial fluid and back.	2. This is case for the transport of water, carbon dioxide, oxygen, and other lipid-soluble substances such as anesthetics and ... alcohol (How NICE!),.
3. In fact, there is a huge amount of blood vessels, especially capillaries, in the brain tissue. The length of all the capillaries together is estimated to cover more than 500 miles!	4. However, the delicate brain tissue must also be protected against noxious material that may be present in the circulating blood.
5. Therefore, the capillaries are NOT permeable to plasma proteins and other large molecules, such as therapeutic drugs. This non-permeability is called Blood Brain Barrier !	6. As you can see in the diagram, the boundary of the capillaries between the blood and the interstitium, which is readily accessible in normal tissue, is firmly closed by tight junctions in the brain; hence the name Blood-Brain-Barrier!

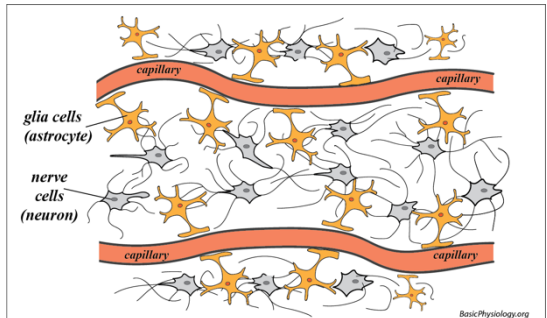
7. Because of this barrier, only the most essential nutrients are allowed to leave the blood capillaries. These essentials are of course the gasses (oxygen and carbon dioxide), and fat-soluble molecules.	
8. In addition, there are also several transport systems available, for example to transport glucose into the brain.	9. Unfortunately, this barrier also makes it difficult or impossible to provide medical treatment such as anti-microbial drugs to the brain.

C. Breaking News: The Glymphatic System.

1. But we are still facing the problem of the lack of lymph vessels in the brain. How does the brain get rid of waste products etc?	2. Breaking news! There is after all, a lymphatic system in the brain but, in several aspects, quite different from that in other organs.
3. There are lymph vessels that are located, together with the arteries, the veins and nerves, in the arachnoid space. This arachnoid space is located between the dura mater and the pia mater, just below the skull:	
4. Together, these layers form the meninges: a) Dura mater (outer layer) b) Arachnoid mater (middle layer) c) Pia Mater (inner layer) <i>Btw, 'mater' is Latin for 'mother'!</i>	
5. But below the meninges, in the brain, there are arteries, veins and plenty of nerves, but no lymph vessels!	6. In the interstitial space, between the neurons, there is still fluid streaming from the capillaries into the interstitial space, to provide oxygen etc. and streaming back to the capillaries to remove CO2 etc.
7. But what about those waste products that do not make it back to the capillaries and that, in	8.

other tissues, are removed by the lymph vessels?	This is where a new system comes in, new because this was recently discovered but, of course, has been there for millions of years! This is the glymphatic system .
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D. The Glia Cells:

1. This diagram displays the architecture of the tissue located in the brain between the capillaries. As you can see, there are capillaries and many nerve cells. But interestingly, there is also another cell type prominently present; the glia cells (also called astrocytes).	 The diagram shows a cross-section of brain tissue. At the top and bottom are red, wavy lines representing capillaries. Between them are numerous orange, star-shaped cells labeled 'glia cells (astrocyte)'. Interspersed among the glia cells are several grey, elongated cells with long, thin processes labeled 'nerve cells (neuron)'. The entire structure is set against a light blue background representing the interstitial space.
2. And, as “promised”, there are no lymph vessels.	3. The current concept of the glymphatic system is that instead of the lymph vessels, there are glia cells that take care of the removal of waste products from the interstitial space.
4. It is not yet fully clear how that is done but one hint can already be seen in this picture; the fact that many glia cells seem to have a ‘foot’ that is located close to a capillary membrane.	5. Recently, an ion channel was found in these “feet” which, when these channels were blocked, led to local interstitial swelling. In other words, the glia cells together with these channels in some ways are responsible for the removal of extra fluid and waste products from the brain tissue.
6. Interestingly, this glymphatic system has only been discovered/described in recent years. When I started studying physiology (some ± 40 years ago; ☺) no one knew anything about this system!	7. However, it must be clear that this is a developing ‘story’ and that many laboratories around the world are now working hard to solve this interesting problem!
8. And, oh yes, why has this new system been called “glymphatic”? Because this word is a junction of “glia” and “lymph”!	

E. Who discovered the Glymphatic System?

1. In 2013, Danish neuroscientist Maiken Nedergaard and her team discovered (and described) the glymphatic system.	2. She gave this system the term ‘glymphatic’ as it is similar to the lymphatic system but also required glial cells for its function.
3. But, as always, in science, she was not the first one (or the last one) to study this system.	4. Previous scientist, such as Rudbeck (18 th century!), Csanda (1966) and many others have also ‘worked’ on the problem of lymph circulation in the CNS. And, as you can now imagine, we will learn much more in coming years!

Basic Physiology Info:

This book collects the text and figures from my website: *BasicPhysiology.org*. This may be useful for anyone who either wants all that info in the same document, a pdf in this case, away from the internet or for any other reason.

What is this book about?

1. This is a simple book, dedicated to teaching the basics of physiology.	2. I have used a similar site for many years, teaching human medical physiology in several medical and para-medical schools.
5. While I am (still) expanding and upgrading this and future chapters, I most certainly welcome your comments, suggestions and/or questions. Feel free to contact me: wlammers@smoothmap.org	<i>Thank you for your interest!</i>  <i>Wim Lammers</i>

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