Dr. King -- Psyc 415

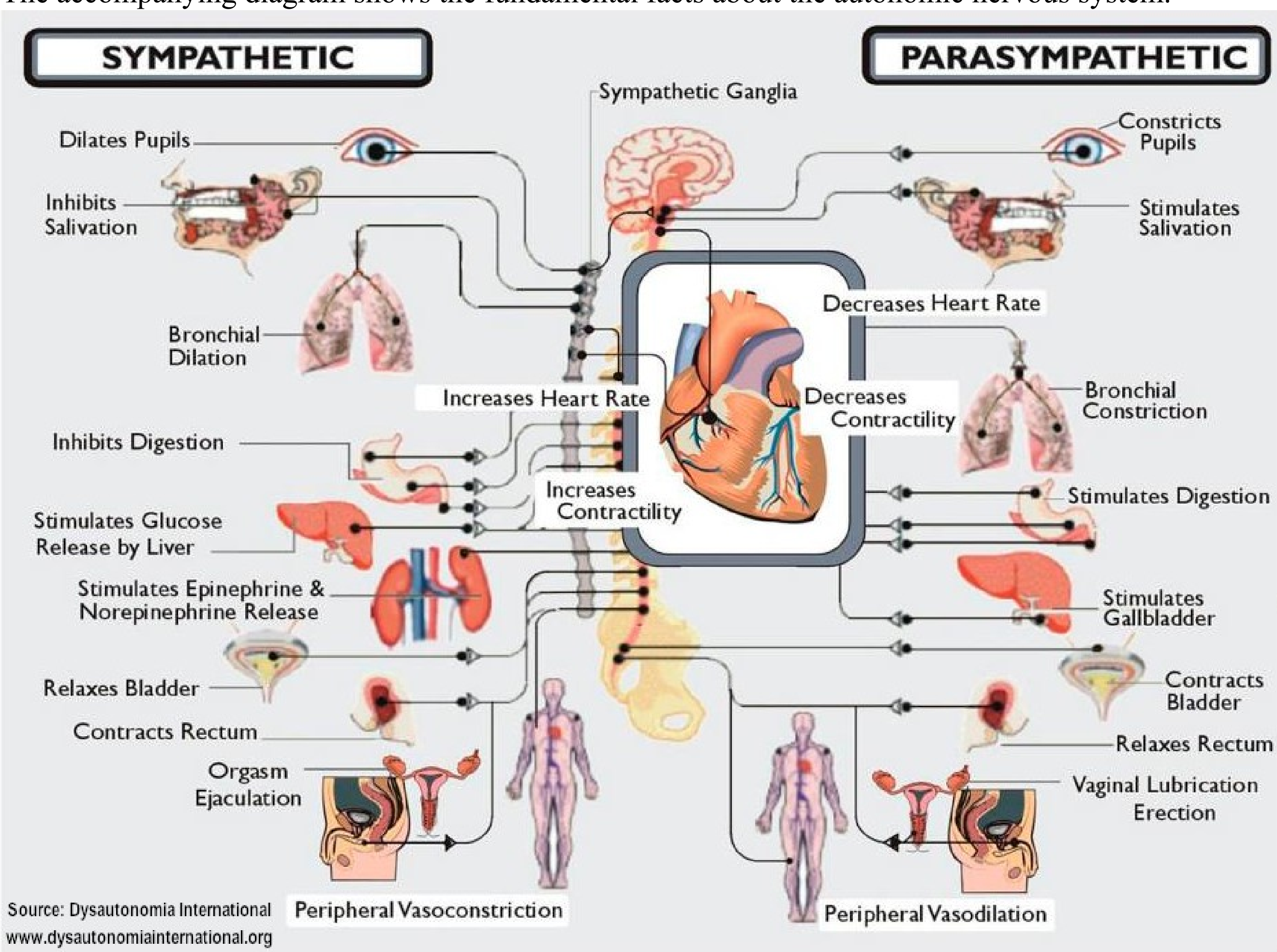
The Peripheral Nervous System

(slides 49-62)

(See slide 49.) The peripheral nervous system consists of the nerves that run throughout the body as well as a number of peripheral ganglia. It can be divided into the autonomic nervous system, which connect the CNS to internal organs, and the somatic nervous system, which connects the CNS to skeletal muscles and carries sensory impulses from sense organs into the CNS.

The Autonomic Nervous System (ANS)

The accompanying diagram shows the fundamental facts about the autonomic nervous system.



The ANS consists of fibers that exit the spinal cord via the ventral root (the part of a spinal nerve that is connected to the ventral horn of the spinal cord) and also certain outgoing fibers that are part of the cranial nerves. These fibers connect the CNS to internal organs of the body. The ANS is divided into two divisions, the sympathetic division or sympathetic nervous system (SNS) and the parasympathetic division or parasympathetic nervous system (PSNS).

The SNS originates from the central spinal cord. In general (but not always), SNS axons leave the spinal cord via the ventral root and then make a synapse immediately outside the spinal cord in a sympathetic ganglion. (This is clearly illustrated on slide 48.) At the synapse in the sympathetic ganglion a neurotransmitter called acetylcholine is released. This activates a so-called post-ganglionic neuron, which then goes to the target organ where it releases a neurotransmitter called norepinephrine (sometimes called noradrenalin). You can see some of the effects of SNS activation in the diagram above: pupillary dilation, inhibition of salivation (dry mouth), increased heart rate, release of stress hormones from the adrenal gland, and peripheral vasoconstriction (raising blood pressure). In general, this constitutes a stress response, and in more extreme cases is called the "fight-or-flight" response. The SNS is preparing the body to respond to an emergency situation. You can feel this response in your body, for example, when someone sneaks up behind you and pops a paper bag behind your head. That "rush of emotion" going through your body is the fight-or-flight response, reinforced by release of the hormones adrenalin and noradrenalin from the adrenal gland.

The PSNS originates from the lower brainstem and lower part of the spinal cord. The first neuron, the pre-ganglionic neuron, exits via the ventral root and travels to near the target organ, where it synapses in a parasympathetic ganglion, releasing acetylcholine as its neurotransmitter. A short post-ganglionic neuron then goes to the target organ, again releasing acetylcholine as its neurotransmitter. Activation has largely opposite effects from those of the SNS: pupillary constriction, stimulation of salivation, decreased blood pressure, and so on. These functions are sometimes referred to as vegetative. That is, the PSNS keeps the body running on an even keel during nonstressful situations. We will find out later that some psychological disorders are characterized by the normal SNS-PSNS balance going out of whack. This happens in depression, for example, in which the body is placed into a more-or-less persistent state of sympathetic activation (stress response).

The Somatic Nervous System

The somatic nervous system consists of sensory neurons arising from the sense organs and entering the spinal cord via the dorsal root of the spinal nerve. These neurons, with few exceptions, release an excitatory neurotransmitter called glutamate at their synapses, which are sometimes in the spinal cord, but sometimes in the brain (recall the fine touch system).

The other part of the somatic nervous system are the outgoing (efferent) motor neurons, which go out and make synapses on muscle fibers of the skeletal muscles to create voluntary movement, the so-called lower motor neurons referred to in a previous lecture. These neurons release acetylcholine as their neurotransmitter.

Cranial Nerves

Now for a good time! There are 31 pairs of spinal nerves, and they are constituted largely as described above. They are called mixed nerves because they contain both sensory and motor fibers. In addition to the spinal nerves, there are 12 pairs of cranial nerves, which are nerves attached to the brainstem. Cranial nerves can be mixed, or they can be purely motor or purely sensory. Slide 50 shows the location of many of the cranial nerve nuclei in the lower brainstem. The sensory nuclei, which receive sensory info from the periphery, have been colored blue, while the motor nuclei, which are the origin of motor fibers going out to control (mostly) muscles of the head and neck, have been colored red. All of these nuclei are bilateral, but to keep them straight, the diagram shows the sensory nuclei on the left and the motor nuclei on the right. Don't bother memorizing the details. That can wait until medical school, or your first course in neuroanatomy in graduate school. (Something to look forward to!)

(See slide 51.) Here is a quick outline of the 12 cranial nerves. This outline is not complete as far as some of the nerves are concerned (do not use it as a reference in other classes!), but it will do for our purposes. Some of these nerves will be discussed in more detail below.

Name of nerve	**sensory/motor**	**innervation**	**function**
I Olfactory	sensory	olfactory epithelium	olfaction (smell)
II Optic	sensory	retina	vision
III Oculomotor	motor ---------------------------- parasympathetic	some muscles of eye movement ---------------------------- muscles in the iris	eye movement ---------------------------- pupillary constriction
IV Trochlear	motor	one muscle of eye movement	eye movement
V Trigeminal	sensory ---------------------------- motor	face, scalp, cornea, nasal and oral cavities ---------------------------- jaw muscles	sensory from the face, mouth, and nose ---------------------------- opening and closing mouth, chewing
VI Abducens	motor	one muscle of eye movement	eye movement
VII Facial	sensory ---------------------------- motor ---------------------------- parasympathetic	part of the tongue ---------------------------- muscles of facial expression --------------------------- salivary glands	taste ---------------------------- movement of the face ---------------------------- salivation
VIII Auditory or Auditory-Vestibular or Statoacoustic	sensory	cochlea and vestibular organs	audition (hearing) and balance (sensation of head movement)
IX Glossopharyngeal	sensory ---------------------------- motor ---------------------------- parasympathetic	middle ear, carotid body, pharynx, part of tongue ---------------------------- throat ---------------------------- salivary glands	general sensation, taste, baroreception ---------------------------- swallowing ---------------------------- salivation
X Vagus	sensory ---------------------------- motor ---------------------------- parasympathetic	pharynx, larynx, aortic bodies, thoracic and abdominal viscera ---------------------------- soft palate, larynx, pharynx, exophagus ---------------------------- cardiovascular, respiratory, and gastrointestinal systems	general and visceral sensation, baroreception ---------------------------- speech, swallowing ---------------------------- visceral PSNS
XI Spinal Accessory	motor	muscles of the neck	movement of head
XII Hypoglossal	motor	tongue	movement of the tongue

(See slide 52.) The olfactory nerve (I) is the shortest of the cranial nerves and the only one that does not terminate or originate in the brainstem. The olfactory nerve serves the sense of smell, originating at olfactory receptors in the nasal mucosa, penetrating the base of the skull, and then immediately terminating in the olfactory bulb on the ventral surface of the frontal lobe. The nerve is easily damaged by skull fractures that displace the bones of the cranium above the nose, resulting in a loss of the sense of smell.

(See slides 53 and 54.) The optic nerve (II) arises from the ganglion cells in the retina and serves the sense of vision. The nerve travels along the ventral surface of the frontal lobe until it reaches the optic chiasm (the big white X) just in front of the hypothalamus, where the fibers (axons) in the nerve partially decussate (as discussed previously) in such a way that information from the right side of the visual field is sent to the left side of the brain, and vice versa. Behind the optic chiasm, this pathway is "officially" in the CNS and becomes known as the optic tracts, although it is still the same axons. These axons terminate (make synapses) in, as I hope you remember, the lateral geniculate nucleus of the thalamus. (A small percentage of the fibers descend and terminate in the tectum of the mesencephalon. Some also terminate in the hypothalamus, in a nucleus that has to do with regulating circadian rhythms in relation to the light-dark cycle.) Cells in the LGN then project their axons to the primary visual cortex in the occipital lobe via pathways called the optic radiations. Obviously, damage to these pathways will result in partial or complete blindness, as illustrated in the diagram on slide 54.

(See slide 55.) The third cranial nerve is the oculomotor nerve (III). In concert with nerves IV and VI, it controls movements of the eye. It also controls constriction and dilation of the pupils. Damage to these nerves will often result in deviation of one or both eyes to one side or the other, in abnormal dilation of the pupil, usually unilaterally, and/or to drooping of the eyelid (ptosis), also usually unilaterally.

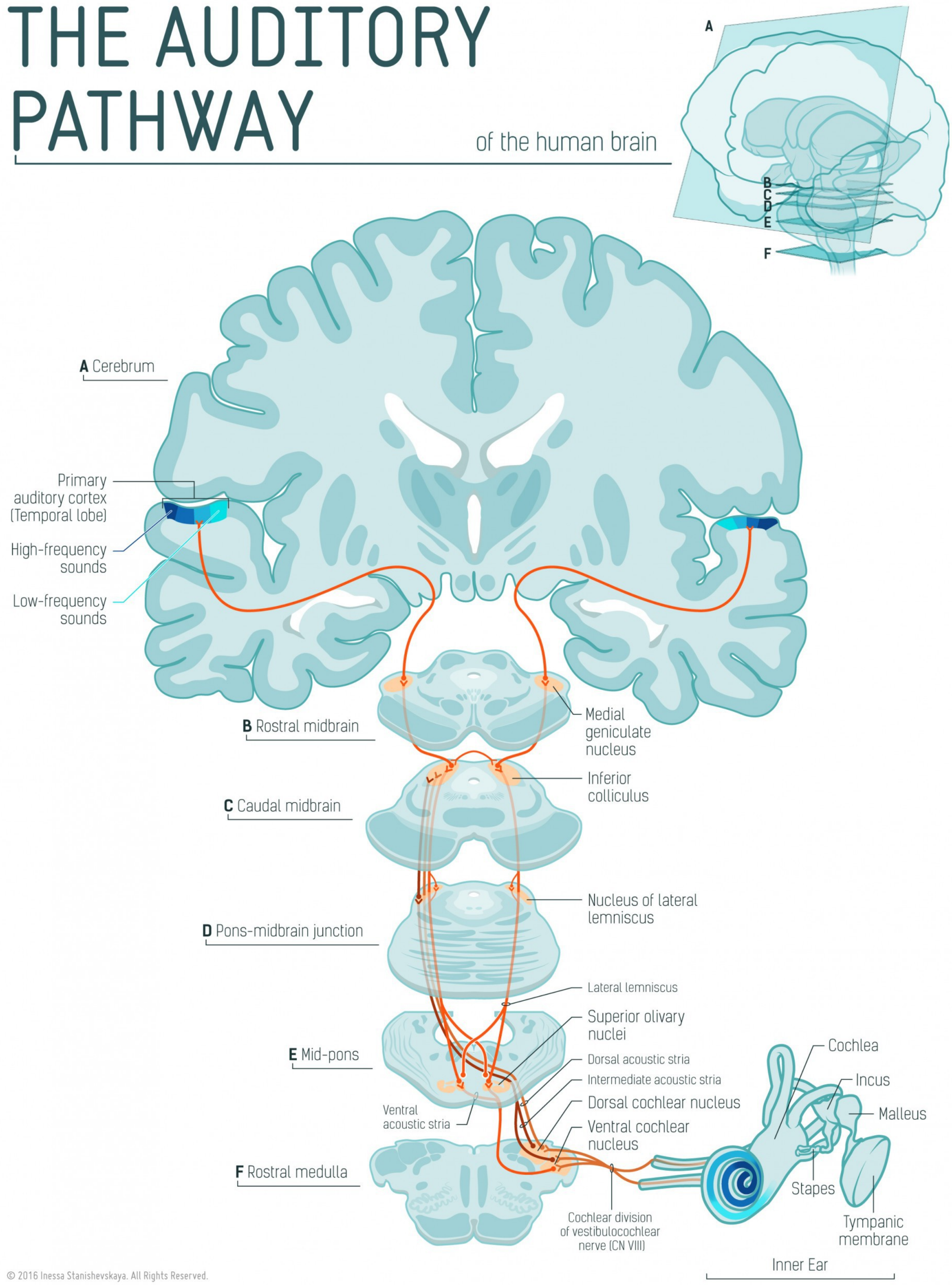
(See slides 56 and 57). The fifth cranial nerve is the trigeminal nerve (V), called that because of its three major branches. While V is in fact a mixed nerve, we will deal only the sensory aspects of its function, sensation from the face, nasal cavities and mouth. When you go to the dentist, and she comes at you with a hypodermic needle full of novocaine, it is the trigeminal nerve she is aiming to anesthetize. Thus, we have almost all felt what its like to have at least one branch of the trigeminal nerve inactivated (numbness on part of the face). A more bothersome problem with the trigeminal nerve occurs when it becomes compressed as it passes through the tiny holes in the skull on its way to the brain. This can result in a very painful disorder called trigeminal neuralgia, the older name for which is tic douloureux (dole-or-rue). This disease can result in very painful, often electric shock-like sensations in the face, usually unilaterally. If your dentist has ever accidentally hit the trigeminal nerve while trying to anesthetize your teeth, you have some idea of what trigeminal neuralgia is like. My dentist seems to be particularly skilled at hitting the trigeminal nerve, which results in a sudden shock-like sensation on the face, jaw, and gums.

(See slides 58 and 59.) The seventh cranial nerve is the facial nerve (VII), once again a mixed nerve, but we will deal only with its motor functions. The facial nerve serves the muscles of the face and facial expression. When the facial nerve is damaged, for example by a small stroke, tumor, or viral infection, the result is loss of muscle control in the face, usually unilaterally. Often the person will get up in the morning, look in the mirror, and see one side of his or her face drooping, which can be a frightening experience. It is most noticeable when the patient is asked to smile, as are the people in the illustrations. The examiner will find that his patient can smile on only one side of his or her face. This condition is called Bell's palsy (or facial nerve palsy) and is most common in older people, but can also occur in younger people. The condition usually clears up on its own in a month or two.

(See slides 60 and 61.) The eighth cranial nerve is a sensory nerve serving the vestibular and auditory senses. It goes by a number of different names, but we will deal with only the auditory functions of the nerve, so we will call it the auditory nerve (VIII). Slide 61 shows the auditory pathways through the brainstem, which we have already discussed a little bit.

The auditory nerve begins at the auditory hair cells in the cochlea of the inner ear and terminates in the cochlear nuclei, which are located near the boundary of the medulla and pons. Cells in the cochear nuclei project their axons across the midline (mostly) to the contralateral superior olive. The superior olive then projects upward through a tract called the lateral lemniscus. These axons terminate in the inferior colliculus in the tectum of the mesencephalon. The inferior colliculus projects to the medial geniculate nucleus of the thalamus, which in turn projects to the primary auditory cortex in the temporal lobe of the telencephalon. Damage to these pathways obviously will result in some degree of hearing impairment, although the exact nature of the impairment depends upon where the lesion is and how extensive it it. Such damage rarely results in complete deafness unless it is in lower brainstem. Lesions in the primary auditory cortex usually result in loss of finer auditory functions such as ability to discriminate pitch, but the person can still hear.

The auditory pathways are summarized in the diagram on the next page for those of you who are more visual learners. (I like diagrams myself.) For a really big version of this diagram, visit http://inessaskaya.com/portfolio/auditory-pathway/.


THE AUDITORY PATHWAY
of the human brain
A
B
C
D
E
F
A Cerebrum
Primary auditory cortex (Temporal lobe)
High-frequency sounds
Low-frequency sounds
Medial geniculate nucleus
B Rostral midbrain
Inferior colliculus
C Caudal midbrain
Nucleus of lateral lemniscus
D Pons-midbrain junction
Lateral lemniscus
Superior olivary nuclei
E Mid-pons
Dorsal acoustic stria
Intermediate acoustic stria
Dorsal cochlear nucleus
Ventral cochlear nucleus
Ventral acoustic stria
F Rostral medulla
Cochlear division of vestibulocochlear nerve (CN VIII)
Cochlea
Incus
Malleus
Stapes
Tympanic membrane
Inner Ear
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