Neurosciences

Somatosensory Pathway

There are three different categories (modalities) of the somatosensory system. The first, discriminative touch, is the perception of pressure, vibration, and texture. This system relies on four different receptors in the skin. They are:

1) Meissner's corpuscles

2) Pacinian corpuscles

3) Merkel's disks

4) Ruffini endings

The somatosensory system includes multiple types of sensation from the body – light touch, pain, pressure, temperature, and joint and muscle position sense (also called proprioception). However, these modalities are lumped into three different pathways in the spinal cord and have different targets in the brain. The first modality is called discriminative touch, which includes touch, pressure, and vibration perception.

The second grouping is pain and temperature.

The third component is proprioception which targets the cerebellum.

Sensation enters the periphery via sensory axons. All sensory neurons have their cell bodies sitting outside the spinal cord in a clump called a dorsal root ganglion. There is one such ganglion for every spinal nerve.

The somatosensory pathway passes through the dorsal (posterior) columns. These posterior columns can be divided into two different tracts called gracile fasciculus and cuneate fasciculus. The gracile fasciculus is carrying all of the information from the lower half of the body (legs and trunk), while the cuneate fasciculus is carrying information from the upper half (arms and trunk).

In the medulla, each tract synapses in a nucleus of the same name. The gracile fasciculus axons synapse in the gracile nucleus, and the cuneate axons synapse in the cuneate nucleus

These nuclei then send afferents which form a new tract called medial lemniscus.

From here they go to the thalamus called the Ventro Posterior Nucleus (VPL) following which they finally synapse in the primary somatosensory cortex.

The pain pathway travels through to the thalamus (VPL) via the spinothalamic tract.

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The proprioceptive system travels to the cerebellum via the dorsal spinocerebellar tract. Nuclei involved here are Clarke's nucleus and external (lateral) cuneate nucleus.

Basic Motor Pathway

The primary motor pathway is also called the corticospinal pathway. As all such pathways are named from beginning to end, this pathway starts in cortex and ends in the spine. Specifically, it starts in the precentral gyrus.

The internal capsule is part of the motor pathway.

The main pathway is called the Lateral (Anterior) Cortico spinal pathway

Central Visual Pathway

Once the ganglion cell axons leave the retina, they travel through the optic nerve to the optic chiasm, a partial crossing of the axons. At the optic chiasm the left and right visual worlds are separated. After the chiasm, the fibres are called the optic tract. The optic tract wraps around the cerebral peduncles of the midbrain to get to the lateral geniculate nucleus (LGN). The LGN is a part of the thalamus. Almost all of the optic tract axons, therefore, synapse in the LGN. The others synapse in the pretectal area (pupillary light reflex)

Pupillary Light reflex: Light enters the retina and from there travels directly to the pretectal area. After synapsing, the information is sent to the Edinger-Westphal nuclei on both sides of the midbrain – this is the crucial step in ensuring that both eyes react to light. The Edinger-Westphal nuclei, via the IIIrd nerve, control the pupillary constrictors that narrow the pupils

Auditory Pathway

The auditory nerve carries the signal into the brainstem and synapses in the cochlear nucleus. From the cochlear nucleus, auditory information is split into at least two streams, much like the visual pathways are split into motion and form processing. One pathway goes to the ventral cochlear nucleus which is responsible for the timing of sound received. The other pathway goes to the dorsal cochlear nucleus which analyses the quality of sound.

The ventral cochlear nucleus cells then project to a collection of nuclei in the medulla called the superior olive. In the superior olive, the minute differences in the timing and loudness of the sound in each ear are compared, and from this you can determine the direction the sound came from. The superior olive then projects up to the inferior colliculus via a fiber tract called the lateral lemniscus.

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From the inferior colliculus, both streams of information proceed to sensory thalamus. The auditory nucleus of thalamus is the medial geniculate nucleus. The medial geniculate projects to primary auditory cortex, located in the temporal lobes.

Basal Ganglia

The basal ganglia and cerebellum are large collections of nuclei that modify movement on a minute-to-minute basis. Motor cortex sends information to both, and both structures send information right back to cortex via the thalamus. The output of the cerebellum is excitatory, while the basal ganglia are inhibitory. The balance between these two systems allows for smooth, coordinated movement, and a disturbance in either system will show up as movement disorders

The name includes: caudate, putamen, nucleus accumbens, globus pallidus, substantia nigra, subthalamic nucleus.

Hypothalamus

The main function of the hypothalamus is homeostasis.

The main inputs are

Nucleus of the solitary tract – this nucleus collects all of the visceral sensory information from the vagus and relays it to the hypothalamus and other targets. Information includes blood pressure and gut distension.

Reticular formation – this catchall nucleus in the brainstem receives a variety of inputs from the spinal cord. Among them is information about skin temperature, which is relayed to the hypothalamus.

Retina – some fibres from the optic nerve go directly to a small nucleus within the hypothalamus called the suprachiasmatic nucleus. This nucleus regulates circadian rhythms, and couples the rhythms to the light/dark cycles.

Circumventricular organs – these nuclei are located along the ventricles, and are unique in the brain in that they lack a blood-brain barrier. This allows them to monitor substances in the blood that would normally be shielded from neural tissue. Examples are the OVLT, which is sensitive to changes in osmolarity, and the area postrema, which is sensitive to toxins in the blood and can induce vomiting. Both of these project to the hypothalamus.

Limbic and olfactory systems – structures such as the amygdala, the hippocampus, and the olfactory cortex project to the hypothalamus, and probably help to regulate behaviours such as eating and reproduction.

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The hypothalamus also has some intrinsic receptors, including thermoreceptors and osmoreceptors to monitor temperature and ionic balance, respectively.

There are two main outputs:

Neural signals to the autonomic system – the (lateral) hypothalamus projects to the (lateral) medulla, where the cells that drive the autonomic systems are located. These include the parasympathetic vagal nuclei and a group of cells that descend to the sympathetic system in the spinal cord. With access to these systems, the hypothalamus can control heart rate, vasoconstriction, digestion, sweating etc.

Endocrine signals to/through the pituitary – recall that an endocrine signal is a chemical signal sent via the bloodstream. Large hypothalamic cells around the third ventricle send their axons directly to the posterior pituitary, where the axon terminals release oxytocin and vasopressin into the bloodstream. Smaller cells in the same area send their axons only as far as the base of the pituitary, where they empty releasing factors into the capillary system of the anterior pituitary. These releasing factors induce the anterior pituitary to secrete any one of at least six hormones, including ACTH and thyroid-stimulating hormone (TSH).

Hypothalamic nuclei and their function

- Medial Pre optic nucleus: contains the sexually dimorphic GnRH nucleus. Release of gonadotropin releasing hormone
- Supra Optic nucleus: oxytocin and vasopressin release
- Paraventricular nucleus: corticotropin releasing hormone, oxytocins and vasopressin release
- Anterior Hypothalamic nucleus: thermoregulation
- Suprachiasmatic nucleus: vasopressin release, circadian rhythms
- Ventromedial nucleus: satiety and sexual behaviour
- Arcuate nucleus: feeding and dopamine release
- Lateral Nucleus: hunger and thirst
- Dorsomedial hypothalamic nucleus: blood pressure, heart rate
- Mammillary nuclei: hippocampus

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