# Sensory systems in animals

All animals have some kind of nervous system that can receive and interpret information about its internal and external environment. Sensory organs provide a means for communication from the external environment to the internal. Sensory receptors contain receptor cells that are specialised to respond to specialised stimuli. These sensory organs may be found all over the body or in localised areas. Afferent neurons carry the sensory information from the periphery toward and into the central nervous system while the efferent neurons carry information away from the central nervous system. Sensations arising when signals initiated in sensory receptors are transmitted in certain parts of the brain, producing signals in certain parts of the brain. (Hickman, Roberts, & Keen, 2009)

Stimulus types possess features that can be distinguished from one another. In the body of an animal the sensory receptor cells are usually modified. For example, certain receptors detect pressure, heat, chemicals, light and even pain. The stimulus for light detection and chemical detection is different and in addition, the same type of stimulus may possess different features. This can be seen, in for example the detection of blue and red light, both being perceived as a stimulus of light.

In the first part of this practical the sensory structures of a number of invertebrate organisms were studied and compared to each other. Mainly chemoreception, photoreception and mechanoreception were studied. Chemicals in the animals surrounding is detected by a number of chemoreceptors. Chemoreceptors may be divided into two main categories; olfactory (smell), which respond to airborne molecules and gustatory (taste), responding to dissolved molecules.

Mechanoreceptors are made up of undifferentiated nerve endings found in connective tissue on the periphery of the animal such as the skin. More complex accessory structures have accessory structures that transfer mechanical energy to the receptive membrane. These mechanoreceptors are also able to filter the mechanical energy and they may also include the muscle stretch receptors

Photoreception consists of transducing photons of light into electrical signals that can be interpreted by the nervous system and photoreceptive organs such as the eyes.

These sensory structures in different animals have taken many different shapes and sizes that have been adapted to the particular environment best for them. Although quite different all the sensory structure of particular receptor has the same function of collecting information from the environment and responding in the best way possible to enhance its survival.

# Apparatus

- Light Microscope cardboard
- Stereomicroscope 1g-5g, 10 g, 20 g, 50, 100 g weights
- Pencil x3 500 mL water bath
- Pointed forceps heater/Bunsen to heat water
- Stop watch thermometer
- X3 5 c coins

# Method

Refer to attached sheet

## Precautions

- The plastomounts were placed under a stereomicroscope for better viewing of small body features
- The same pair of forceps was used to apply the stimulus since different instruments could result in different outcomes.
- As much as possible the coin was placed in the sample place for all subjects since different area may have a different amount of receptors.
- The temperature in the water baths was measured before the experiment was conducted. This was done so that the initial temperature of the water for all the subjects would be the same. Thus the results would be more comparable.

## Sources of Error

- Due to the clothing worn the experiment of tactile response using the forceps had to be carried out over the clothing. This thus formed an extra layer that could decrease the response of the nerve.
- Not all the sensory structures of the organisms may have been identified.
- The experiments on each subject were only carried out once. More accurate results would have been obtained if carried out at least 3 times

## Results Part A

Refer to attached diagrams

## Thermoreception

For all 3 subjects the cold water was almost painful, while the water at 45 degrees was soothing. On placing the hand in the water at room temperature the right hand felt the water warm while the left hand (previously in the warm water) felt the water cold.

# Discussion

## Part A: Invertebrates

These sensory structures in different animals have taken many different shapes and sizes that have been adapted to the particular environment best for them. These mainly have evolved from simple to more complex sensory organs that enhance the ability of the animal in collecting information from the environment and responding in the best way possible to enhance its survival.

The Cnidarian Hydra, has relatively simple sensory cells scattered all over the body among the other epidermal cells, especially the mouth and tentacles. It is of utmost importance for sensory structures to be located all over the body due to the fact that the animal is radially symmetrical and can detect stimuli from all direction, including the detection of predators. The free end of every sensory cell bears a flagellum, which is the sensory receptor for chemical and tactile stimuli. The other end branches into fine processes, which synapse with nerve cells. On the surface of the animal is a modified cilia called a Cnidocil, that when simulated by any mechanical stimulation releases a nematocyst that is toxic to the predator. (Barnes & Cawlow, 2002)

These sense organs then lead into a diffuse nerve network, forming two interconnected nerve nets. It is of utmost importance for sensory structures to be located all over the body due to the fact that the animal is radially symmetrical and can detect stimuli from all direction, including the detection of predators. (Hickman, Roberts, & Keen, 2009)

From the radially symmetrical Cnidarian one can move on to the bilaterally symmetrical Platyhelminthes that is represented here by the Planaria. Here the nervous system is organised into two longitudinal nerve chords that end in the anterior of the animal. This forms an anterior head and cephalisation is introduced. (Hickman, Roberts, & Keen, 2009) The Planaria, unlike the Hydra are seen to have an eye spot and auricles. The auricles are lobe like and are found on the sides of the head. The auricles act as a means of chemoreception while the eye spot serves as photoreceptor detecting light. Like the Hydra, it may also contain a statocyst for equilibrium and rheoreceptors for sensing water currents. Cephalisation allowed the animal to develop a bilaterally symmetrical shape. The animal moved forward and can detect changes in the environment with the part of the body with the most sensory organs, its anterior region. (Leineschh, 2007)

The Pulmonate gastropod, belonging to the class Gastropoda is seen to further develop its sensory in the anterior of the body. In the anterior of the body the animal is seen to have paired eyes that function as photoreceptors, even though they are not capable of forming an image. Also the labial and cephalic tentacles are mechanoreceptors, sensitive to tactile stimuli, and are probably also chemoreceptive. (Hickman, Roberts, & Keen, 2009)

The general body surface is also sensitive to chemical and mechanical stimuli. The gastropod also has a structure that acts as both a mechanical and chemoreceptor. This is seen to be the osphradium which is located in the inhalant respiratory water current where it monitors water on the way to the gill. A common structure with the previously studied animals is the statocyst which functions as a detector of gravity. (Hickman, Roberts, & Keen, 2009)

The next three species studied all belong to the phylum Arthropoda, but are found in different classes. The first to be studied was the Tarantula found in the class Arachnida (order Aranea). This animal has hair like receptors called sensory setae that function as mechanoreceptors all over the body of the animal. Also, in addition they have small, extremely sensitive tactile hairs called trichobothria that are sensitive to even airborne vibrations, including sound frequencies. Chemoreception is associated with fine hairs surrounding the mouth, on the pedipalps. (Hickman, Roberts, & Keen, 2009)

The tarantula also has 8 simple eyes that are made up of a lens, optical rods, and a retina. Even though most only can detect movement like the previously studied animals, some are able to form images. Since the spider is more accustomed to capturing prey within webs, vision is relatively unimportant and thus in most remain simple. (Underwood, 2009)

Another member of the phylum Arthropoda is the scorpion, classified in the class Scorpionida. Although they are equipped with venom for defence the scorpion is still seen to be the prey of many other animals, thus they require specialised sensory structures for detection of danger. This animal is seen to possess a unique sensory structure know as a pectine. This is used primarily in detecting vibrations which are used for capturing prey. (Gaoge & Smith , 2000)

This is seen to be the primary chemosensory organs of scorpions. The pectines are found in the ventral medial part of body and are seen to be paired appendages that brush the substrate as the scorpion walks. Comb-like organ consists of a supportive spine and an array of teeth. Each tooth supports hundreds of setaform sensilla called pegs. The neuronal cell layer within the teeth is seen to be further divided into inner and outer sub-larninae, comprised of chemosensory and mechanosensory neurons. (Melville, 2000)

Similar to the arachnids described previously, the scorpion has sensory hairs called setae that function as tactile and chemosensory hairs. These sensory hairs are also found on the pedipalps of the animal to sense air-borne vibrations. Also, thicker setae are found all over the body to detect direct touch. In contrast to the spiders the scorpions possess six pairs of eyes as part of their photoreceptor structure.

The last arthropod group to be described is the centipede, classified into the sub-phylum Myiapoda and order Centipedes. These animals are seen to possess one pair of antennae instead of the usual two paid found in other arthropods. The antennae are sensory appendages found in the head of the animal that are sensitive to airborne chemicals and also possibly humidity. Similar to the planaria, Centipedes also bears a pair of simple eyes made up of ocelli. (Barnes & Cawlow, 2002)

## Part B: Sensory function in Mammals

### Mechanoreception

Somatosensory system has a large number of receptrors which vary in location and type. Receptors are located in the superfial skin, dermal, epidermal and depper in dermis, and in subcutaneous tissue. Meissner's corpusles are located in the dermal papillae, Merkel's receptors in the dermal papillae, and bare nerve endings. Subcuateous receptors, beneath both the previously mentiones layers, possess pacinian and Rufflin corpusles. Pacinian may be both cutaneous and subcutaneous. (Wang , 2007)

The Pacinian corpusles are present in the skin, muscles, mesentery, tendons, and joints of mammals that are rapidly adapting. Each Pacinian corpuscle contains a region of receptor membrane that is sensitive to mechanical stimuli and that is surrounded by concentric lamellae of connective tissue structures (Anonymous, 2007)

Pressure on the corpuscle transmits mechanically through the layers to the sensitive membrane of the receptor neuron. The receptor membrane normally responds with a brief, transient depolarization at both the onset and the offset of the deformation. The mechanical properties of the intact corpuscle, which preferentially pass rapid changes in pressure, confer on the receptor neuron its normally phasic response. (Randall, Berggren, & French, 1997)

This behaviour explains why the sensation of the coin was lost after a few seconds. The added coin did not produce enough mechanical force to excite the Pacinian corpustle once again, thus it was not felt. The time taken for the coin to stop being felt varied from person to person. This could be due to the different amount of tissue between the skin and the nerve. The thicker the less the coin is felt and the quicker is sensation is lost.

A mechanoreceptor’s receptive field is the area within which a stimulus can excite the cell. If the skin is touched in two separate points within a single receptive field, the subject will be unable to feel the two separate points. If the two points touched span more than a single receptive field then both will be felt. The size of mechanoreceptors’ receptive fields in a given area determines the degree to which detailed stimuli can be resolved: the smaller and more densely clustered the receptive fields, the higher the resolution. For this reason, the density of the Merkel nerve endings and Meissner’s corpuscles determine the sensitivity of the particular area. (Wang , 2007)

From the results obtained the fingertip is seen to be the most sensitive and thus will have a high density of Merkel nerve endings and Meissner’s corpuscles. On the other hand the fore arm is seen to be one of the least sensitive and thus will have a small density of the nerves

Besides physical contact detected by mechanoreceptors, more complex accessory structures are able to transfer mechanical energy to the receptive membrane. These most complex accessory structure associate with mechanoreceptive cells is the vertebrate middle and inner ear.

Hair cells are found in all vertebrate animals including humans, and are extremely sensitive mechanoreceptors. They are responsible for transducing mechanical stimuli to electrical signals.

They are found in several locations. For example, in vertebrate fish and amphibians, an external set of receptors are called the lateral line system. This system is based on series of hair cells that detect motion in the surrounding water and when stimulated produces an action potential as in the mammalian ear. This lateral line is, however, not present in mammals. (Hickman, Roberts, & Keen, 2009)

The ears of vertebrates perform two sensory functions. The organs of equilibrium perform like the statocysts in invertebrates that allow the animal to detect its position with respect to gravity. The organ of hearing provides formation about vibrational stimuli in the environment, thus detecting sound. (Hickman, Roberts, & Keen, 2009)

Sound waves enter the external ear of a vertebrate aided by the pinna and the tragus. The entire external structure has a function similar to that of a funnel, amplifying and then concentrating sound waves. Vibrations from sound waves cause changes in air pressure, which travel from the external ear, down the auditory canal, and then move the eardrum.

The ear converts energy of sound into nerve impulses. The vibration of the eardrum causes the fluid of the cochlea to move. The basilar membrane containing the floor of the cochlea, and the scala media, containing the organ of corti is where these vibrations undergo the conversion to neuronal impulses. The organ of corti contains sensory hair cells, and the waves of fluid in the cochlea press the hair cells against an overhanging tectorial membrane, and then pull them away. These hair cells are just across synapses from sensory neurons, and this action provides a stimulus that opens sodium channels in the sensory cell membranes. This provides for an action potential in the environment of high potassium concentrations that the endolymph has. Auditory nerves located in a spiral ganglion carry the action potential to the brain. (Randall, Berggren, & French, 1997)

Invertebrates, such as the insects have ‘ ears’ located on their thoracic legs and are associated with respiratory passages, called the trachea. The ear tympanum has an analogous function to the tympanic membrane of the mammalian ear. Similar to a mammal, sound waves stimulate the membrane to vibrate, but in the insect, this directly activates nerve impulses. (Barnes & Cawlow, 2002)

Some insects also have a related tracheal system that directs information on air pressure changes, inside the insect, to the eardrum. If the right tympanum is stimulated, it will send the signal through the tracheae to the left tympanum. The delay in stimulus between the left and the right ear helps the insect locate the direction from which the sound came.

Weber’s law states that the ratio of the difference threshold to the value of stimulus is constant. According to this relationship, doubling the value of the stimulus will cause a doubling of the difference in the threshold. As seen in the results the just noticeable difference or intensity difference for the 50 g and 100 g was seen to be constant for all the subjects.

**Chemoreception**

Vertebrates, including humans detect chemicals using general receptors and two types of specialized receptors, gustatory and olfactory. Many aquatic vertebrates have generalized chemical receptors scattered over their body surface. Vertebrates usually accomplish chemoreception by moving chemically rich air or water into a canal or sac that contains the chemical receptors. Mammals together with other vertebrate have taste receptor cells located in taste buds which are supported by basal cells.

Chemoreception is much different in invertebrates than in vertebrates. For example, planarians find food by following chemical gradients in their surroundings. Their simple chemoreceptors are found in pits on their bodies, over which they move water with cilia. Insects have chemoreceptors in their body surface, mouthparts, antennae, forelegs, and, in some cases, the ovipositor. Moths, for example, smell with thousands of sensory hairs on their antennae. (Barnes & Cawlow, 2002)

**Photoreception**

In vertebrates such as humans, the surface of the eyeball is made up of the sclera, a white connective tissue, and under that a thin pigmented layer called the choroid. The sclera contains the cornea which is transparent, and is where light initially enters the eye, and the choroid contains the iris which contracts and expands to regulate the amount of light entering the hole in its centre, known as the pupil. The rear internal surface of the eye is the retina, which contains the actual photoreception cells. In the retina, there are two types of receptor cells, rods and cones. Rods and cones contain visual pigments made up of light absorbing retinal molecules. (Randall, Berggren, & French, 1997)

Compound eyes of arthropods are image forming eyes composed of many optic units called ommatidia. These are able to detect a very small fraction of the spectrum of light that the eye as a whole is exposed to; like the rods and cones of the vertebrate eye. In compound eyes, the photoreception cells are called retinular cells, and they surround a single eccentric cell. Because the receptive field of each unit in a compound eye is relatively large, compound eyes have lower visual acuity than vertebrates. (Randall, Berggren, & French, 1997)

**Thermoreception**

Temperature is an important environmental variable, and many organisms acquire sensory information about temperature from the action of specialized nerve endings known as thermoreceptors, in the skin. Both the external skin and upper surface of the tongue of mammals contain ‘ warmth’ and ‘ cold’ receptors. the ‘ warmth’ receptors detect an increase in temperature in the environment by increasing the firing rate transient. On the contrary cold receptors increase its firing rate transient when a cool environment is detected. (Randall, Berggren, & French, 1997)

These receptors are quite sensitive. Their firing rate is seen to increase the more the temperature of the external environment varies from the internal body temperature of about 37 OC. when the temperature becomes sufficiently different the patter changes for both types of receptors and the frequency of the action potential is seen to drop. The response of the thermoreceptors consists of a large transient change in firing rate, followed by a longer-lasting, steady-state phase.

Other sensory structures that are not present in humans also exist. For example, snakes have thermoreceptors that are able to detect emitted heat energy. This is advantageous for them to detect warm-blooded prey. Also fish are able to use very low frequency electrical signals to communicate in murky water, thus they are able to locate each other. (Hickman, Roberts, & Keen, 2009)

## Conclusion

From this experiment it was concluded that different organisms have different sensory structures adapted to their unique modes of life. One could also not that as animals become more complex, their sensory structures are also seen to be more developed. This can be seen from the evolution of the simple eye spot in planaria to the complex eye found in humans. Not only are humans seen to be able to detect movement but also colour. However, one may also note that humans do not always possess the most advanced sensory structures. This can be seen in for example, the ability of reptile snakes to detect infrared radiation. This being absent in humans.