Nervous system - sensory input.

Overview:

Sensory neurons are designed to register certain chemical, physical, electrical or other stimulus.

If this stimulus is strong enough, this sets off an action potential.

This impulse is then transmitted to the appropriate part of the nervous system.

Incidentally, the perception of "light", "sound", etc. is not determined by the "receptor", but rather on how/where the signal winds up (mostly in the brain).

As a silly example: suppose we could unplug nerves coming into the brain from the eyes. Instead, we plug in nerves coming from the ears.

Now sound would be registered as "light", but who knows what this would be interpreted as.

There are 5 main categories of sensory receptors (actually, lots more, but these will do for now):

Mechanoreceptors - mechanical changes (pressure, touch, etc.).

Pain receptors - sense pain.

Thermoreceptors - temperature receptors.

*Chemoreceptor*s - taste, smell, other chemical receptors.

Electromagnetic receptors - light, other electromagnetic waves.

[Notice that this list really has nothing to do with the proverbial "5 senses"].

Mechano, pain & thermo receptors.

In the skin - a lot of these come together in the skin and form our sense of "touch" **[Fig. 29.3A, p. 590]**.

Touch is actually made up of several different receptors.

Pain - this is very important and causes a strong negative reaction. This helps us avoid damage.

Leprosy is a disease which (among other things) can shut down pain receptors.

Mechanoreceptors in the skin:

Deep touch (pressure) - for example, what you feel when sitting down.

Light touch (often assisted by hairs) - used to determine texture, air currents, etc.

Thermorecptors:

Separate receptors for hot and cold (separate) exists.

They're not evenly distributed (for example, the chest has an excess of cold receptors).

In general, the distribution of these receptors is not evenly distributed throughout the body.

Many more receptors in the fingertips and other "sensitive" areas; fewer along the back and so on.

Hearing/equilibrium - these are mechanoreceptors.

Sound, for example, is made up of vibrations of air molecules which travel from the source to your eardrum and then set off vibrations there.

The ear **[OVERHEAD, fig. 29.4A-C, p. 592 - 593]**:

Outer ear

Pinna (the earlobe) - this collects and channels sound into the auditory canal

Auditory canal - funnels sound to the eardrum.

Eardrum - vibrates in response to sound and pushes against the middle ear.

Middle ear

Three bones:

Hammer (or malleus) - transmits vibrations to the anvil.

Anvil (or incus) - transmits sound to the stirrup.

Stirrup (or stapes) - conducts sound to the oval window (and from there to the inner ear).

The purpose of these bones is to mechanically amplify sound.

The middle ear is "gaseous", in other words, these three bones are surrounded by air.

This requires a way to equalize the pressure on both sides of the eardrum.

Eustachian tubes - allow air from the outside into the middle ear

The eustachian tubes open up when yawning or swallowing and let air from the outside move in or out of the middle ear.

If the eustachian tubes are blocked, this can be quite painful if the pressure changes are large.

Inner ear

The stapes thump on the "oval window", which opens onto a rather complicated structure with two main functions: hearing and balance.

The part of the inner ear used for hearing is the *cochlea* **[Fig, not in book]**.

The oval window transmits vibrations into a fluid that's in the upper (vestibular) canal.

This canal eventually rounds a corner and enters the lower (tympanic) canal.

At the end of the lower canal, any leftover vibrations are damped by the *round window*.

Between the two canals there's the middle canal (cochlear duct) **[previous fig., 29.9]**.

The fluid in the upper and lower canals vibrate against this middle canal

As it does, it causes hairs inside the *Organ of Corti* to brush against the *tectorial* membrane.

These hairs trigger nerve impulses which are then carried up the auditory nerve.

Volume is determined by the number of hairs triggered.

Pitch is determined by the location of the vibrations (not all parts of the middle canal will vibrate in response to a specific frequency).

Healthy humans (younger) can hear from about 20 Hz (low) to 20,000 Hz (high).

(1 Hz = one vibration/second)

Bats:

Can hear to well over 100,000 Hz (there is some evidence that some can hear sound frequencies over 160,000 Hz).

They use sound to navigate, catch prey, and other things.

Bats generate sound waves

Bats often have strange protrusions on their face and ears that help them to make/focus sound.

Bats are actually very noisy - be happy you can't hear them!

These sound waves bounce off objects, and then comes back to the bat.

As the signal is modified by the various objects it bounces off of, the bat can tell numerous characteristics about these objects:

location/speed/size/texture.

This use of sound waves is called *echolocation*.

Amazingly, even with several million bats, each bat can sort out it's own signals!

Other animals with echolocation include whales, dolphins and possibly some moles.

In contrast, elephants can hear below 20 Hz.

Balance & movement **[Fig. 29.5, p. 594]**:

Movement - uses three *semicircular canals*, all at right angles to each other.

Each is filled with a heavy fluid.

As the head is moved, this fluid has inertia (doesn't want to move).

This inertia is sensed by hairs at the base of each canal, and this tells the brain which way the head was moved.

Balance - sensed by the *utricle* and *saccule*:

These are basically filled with fluid and *otoliths* (basically little deposits in the utricle and saccule (think of them as little pebbles)).

These otoliths set off information about the position of the head.

Chemoreceptors - taste and smell.

Extremely important for most animals.

Humans have become much more visually oriented and don't have a good sense of smell.

[Birds don't either, with a few exceptions - any guesses as to which??].

Taste - chemicals in solution.

In humans, taste is determined by different parts of the mouth.

Taste receptors in different parts of the mouth respond to salt/bitter/sugar/sour/fat.

This is probably this is because these are the most important things to sense about food.

But note that what we consider "taste" is usually "smell".

Smell - chemicals in air.

In humans (mammals) smell is determined as follows**[Fig. 29.11, p. 599]**.

A substance binds to a specific receptor molecule on the surface of the chemoreceptor cells.

There are about 1000 or so different receptors, each of which is specific for a certain shape of molecule

But mammals can detect a much greater range of smells!

This is not well understood, but may have to do with how well a molecule fits a specific receptor and how many receptors are triggered.

Humans can detect about 10,000 different smells in high concentrations.

Dogs - are more sensitive because they have many more receptors of each type (they only have about 1000 different receptors (like us), but many more of each).

Among mammals, bears probably have the best sense of smell.

Some examples of smell / taste:

In insects, taste receptors may be in the feet and mouthparts [i.e., when a fly is walking over your food....]. Other chemoreceptors are often located in the antennae.

Salmon and turtles use the sense of smell to navigate to the place of their birth based on minute chemical cues (at birth, the chemical cues of the environment are imprinted).

Electromagnetic receptors (e.g. sight)

The idea is to detect electromagnetic waves, usually light.

The eye (using the human eye as an example) **[OVERHEAD, fig. 29.7C p. 595]**:

Sclera - the tough white outer layer surrounding each eye ("whites of the eye").

Choroid - a thin pigmented layer just inside the sclera.

In humans, this is black and absorbs reflections.

Nocturnal animals may have a *tapetum*, or reflective layer in the choroid that helps increase night vision.

At the front of the eye, the sclera is transparent and forms the *cornea*.

The cornea focuses light onto the *lens*.

Near the front of the eye, the choroid forms the iris

The iris can open or close the pupil depending on light intensity.

The iris also determines eye color.

Further in, *ciliary muscles* control the shape of the *lens*.

These muscles change the shape of the lens so that you get a clear (focused) image on the retina. Details below.

Retina - the layer of light sensitive cells that detect light energy. Details are below.

Aqueous humor - the liquid between the lens and cornea.

(*Humor* is an old fashioned term from liquid)

Vitreous humor - the liquid between the lens and retina.

Focusing light - details of the lens **[Fig. 29.8, p. 596]**:

When the ciliary muscles are relaxed, this puts tension on the *suspensory ligaments*, and the lens becomes "flat"

This allows you to focus on distant objects.

When the ciliary muscles contract, this releases tension on the suspensory ligaments, and the lens becomes round

This allows you to focus on near objects.

With age, the ability of the lens to become round becomes less; this often requires you to get "reading glasses" (you can't see things up close easily).

Some details on the retina **[previous Figure]**:

The retina consists of *rod* and *cone* cells.

Rod cells in humans are more common around the sides, cone cell more common towards the center.

Rods are more sensitive to light than cones, but only see black and white (no color).

Cones are less sensitive to light, but see in color.

They come in three different varieties, red, blue, and green sensitive (some editions of your text say yellow - this is wrong).

Adding up these colors will give complete color vision.

Notice that TV sets and computer monitors operate on a similar principle (hold up a magnifying glass to your smart phone - you'll notice three little dots, red, blue and green).

Animals that are more active at night are more likely to have rods than cones.

Even humans see more black and white when it's dark (color requires more light).

Color vision among mammals is highly variable:

Humans having good color vision

Many others have hardly any color vision (dogs actually do have some color vision, but it's nearly as good as ours).

Fovea - this is the area at the back of the eye where cones (in humans) are particularly dense. When looking straight ahead, people focus light directly on the fovea.

Humans have between 100,000 to 150,000 cones in the fovea

Birds (hawks, falcons) may have over 1,000,000 cones.

Blind spot - this is the area where the optic nerve comes in, so there are no rods or cones.

Light that falls on the blind spot can't be detected (no rods or cones).

Depth perception:

The signal from the eyes actually crosses at optic chiasma. Information from the right sides of both eyes goes to the right of the brain, and vice-versa **[Fig., not in book]**.

Specific cells in the brain will get the signal from both eyes and by resolving the discrepancy in position will provide depth information (i.e., binocular vision).

In other words, the image doesn't fall on the same part of the right and left eye, and the brain uses this discrepancy to figure out how far away something is.

Other electromagnetic receptors and some comments:

The infrared pit of some snakes can register heat (for example, the heat of a mouse).

UV sight of insects (use eyes) - insects can see in UV, and can see patterns and shapes that are invisible to us (particularly on flowers).

Finally, a few other senses, that don’t fit in with the breakdown given above:

Electric sense of fish

Sharks and electric eels use electrical fields generated by organisms to sense theses organisms.

Magnetic sense of birds

Birds can sense the magnetic field of the earth and use this to help them navigate (though this is generally used as a back-up system, since it’s not that accurate).

There are also other senses (e.g., ph sensors, osmotic sensors, etc.).