Nervous system, part II - sensory input.

Overview:

- sensory neurons are designed to register certain chemical, physical, or electrical events (this is broken down further below).

- if the stimulus is strong enough, this sets off an action potential.

- this impulse is then transmitted to the appropriate part of the nervous system. 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).

- silly, but suppose we could unplug nerves coming from eyes, plug in nerves coming from ears. Now sound would be registered as "light", but who knows what it would be interpreted as.

Sensory receptors - types:

- 5 categories
    - mechanoreceptors
    - pain receptors
    - thermoreceptors
    - chemoreceptors
    - electromagnetic receptors

[This list has nothing to do with the proverbial "5 senses"].

1) mechano, pain & thermo receptors:

- A lot of these come together in the skin. **[Fig. 29.3A, p. 590** (not very good figure, though)**]**.

    - touch is actually made up of several different receptors, most of which are sensory neurons (which wind up in the CNS).

    - pain - very important --> causes negative reaction --> move away from stimulus

        - leprosy (among other things, shuts down various pain receptors)

    - touch - several different categories

        - some sense deep touch (i.e.,sitting down)
        - light touch (often assisted by hairs)
        - light touch - detect air currents.
        - heat/cold (separate) sensors for heat or cold are not necessarily evenly distributed (for example, the chest has an excess of cold

receptors).

- also note that overall these mechanoreceptors are not evenly distributed throughout the body. There are more in the fingertips and other "sensitive" areas, and fewer along the back and similar areas.

- hearing/equilibrium - sound is mechanical. Vibrations of air molecules are responsible for sound transmission. These vibrations are picked up by the appropriate structures.

- Ear (mostly as in mammals) **[OVERHEAD, fig. 29.4A-C, p. 592 - 593]**:

  - outer ear; three parts:
    - pinna (collects, channels sound)
    - auditory canal (funnels sound to the eardrum)
    - eardrum (takes sound and pushes against the malleus)

  - middle ear:
    - malleus (or hammer) transmits vibrations to the:
    - incus (or anvil), which transmits sound to the:
    - stapes (or stirrup).

      - purpose --> sound amplification. These three little bones work together to mechanically amplify the sound.

      - the stapes conducts sound to the inner ear through the "oval window"

    - note that middle ear is "gaseous", i.e, the bones are not in a fluid. The eardrum thus divides two "gaseous" areas.

      - If the outside pressure changes, this needs to be equalized --> yawning, swallowing, etc. open eustachian tubes to outside (from the back or the throat) and this allows the pressure to equalize.

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

    - the inner ear is filled with a fluid that moves around in response to movement or sound.

    - the part of the inner ear used for hearing is the cochlea.
      - **[Fig, not in book]**
      - oval window thumps onto the fluid in the upper (vestibular) canal.

- canal goes around a bend and then enters the lower (tympanic) canal.
- at the end, energy is dissipated against the "round window".
- the middle canal (cochlear duct) sits between these two canals.
- **[previous fig., 29.9]**
- fluid in these canals vibrates against this duct. As it does, various hairs inside the Organ of Corti brush against the "tectorial" membrane which sits over this organ. This triggers nerve impulses which are then transmitted to the auditory nerve.
- pitch - determined by location/length of hairs (see overhead (longer fibers or hairs are near the apex, shorter ones near the base)).
- volume - determined by frequency (number of) of "hairs" and therefore action potentials generated.
- healthy humans (younger) - can hear from about 20 Hz (low) to 20,000 Hz (high).

- bats:
    - can hear to well over 100,000 Hz. (some evidence for up to 160,000 Hz)
    - use sound to navigate.
    - bats generate sound waves (strange protrusions on face and ears are used to do this).
    - 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
        - even with several million bats, each bat can sort out it's own signals!
    - the bat can also change its signal depending on the situation.

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

- each is filled with a heavy fluid.

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

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

balance - by "utricle and saccule":

- basically filled with fluid and "otoliths". Otoliths rest against base of these sacs and send information about head position.

2) chemoreceptors - sense of 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 couple of exceptions - any guesses as to which??].

- taste - chemicals in solution.
- smell - chemicals in air.

- 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.

- 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 is determined as follows (in mammals) **[Fig. 29.11, p. 599]**:

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

- there are about 1000 or so receptors, 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 (illustrate).
- humans can detect about 10,000 different smells in high concentrations.

- dogs - are more sensitive because they have many more receptors in each class (not because they have more "classes" of receptors. Dogs can thus distinguish an almost unlimited number of different smells.

- these nerves eventually transmit the signal directly to the olfactory bulb of the brain [remember this when we discuss the brain].

Some other examples of smell:

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

3) electromagnetic receptors (e.g. sight)

- the object is to detect electromagnetic waves, in particular, light.

- in vertebrates:
  - details (human eyes) **[OVERHEAD, fig. 29.7C p. 595]**:

  - sclera - tough white outer layer surrounding each eye.

  - choroid - thin pigmented layer just inside the sclera (some mammals may have a "tapetum", or reflective layer in the choroid

  - this helps animals in night vision by reflecting light back onto the retina).

  - at the front of the eye, the sclera is transparent and forms the "cornea".

  - the cornea focuses light onto the lens.

  - at the front of the eye, the choroid forms the iris (which also determines eye color).

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

  - further in, ciliary muscles control the shape of the lens.

  - the lens is adjusted so that the shape of the lens makes a clear (focused) image on the retina.

  - retina - the layer of light sensitive cells that detect light energy. Details soon.

  - between the lens and cornea --> aqueous humor

  - between the lens and retina --> vitreous humor

  - lens: details **[Fig. 29.8, p. 596]**:

    - when the ciliary muscles are relaxed, this puts tension on the suspensory ligaments, and the lens becomes "flat", which helps to focus on distant objects.

- when the ciliary muscles contract, this releases tension on the suspensory ligaments, and the lens becomes round, which helps focus on near objects. With age, the ability of the lens to become round becomes less, requiring "reading glasses".

- remember, the ciliary muscles are arranged in a circle, so when they contract, they make the "circle" smaller. This is not real clear from the figure.

- retina: details **[previous Figure]**

- 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) [mention stars].

- cones come in three different varieties, red sensitive (NOT yellow, like your book says), blue sensitive, and green sensitive. Adding up these colors will give complete color vision.

- TV sets and computer monitors operate on a similar principle (hold up a magnifying glass to your TV set - 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.

- Color vision among mammals is highly variable:

- humans having good color vision

- many others have hardly any color vision.

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

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

- 100,000 - 150,000 for humans.

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

- Depth perception:

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

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

2) other electromagnetic receptors and some comments:

- infrared pit of snakes can register heat

- UV sight of insects (use eyes)

3) 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).