Introduction

Visual Perception

Aditi Majumder, UCI

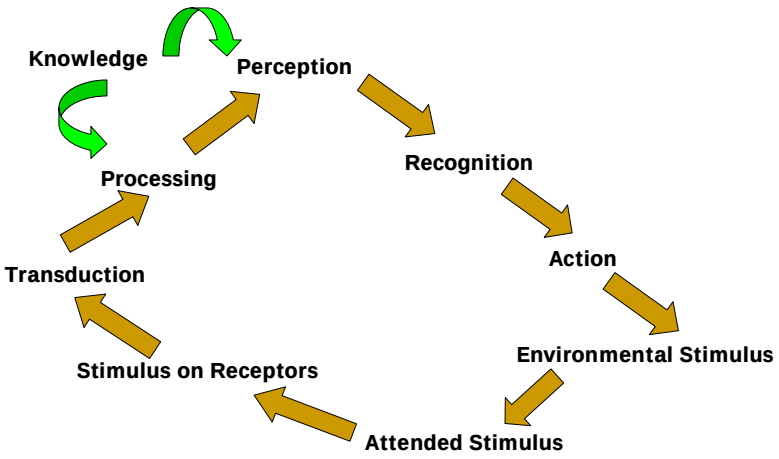
Perception is taken for granted!

Perception is very complex

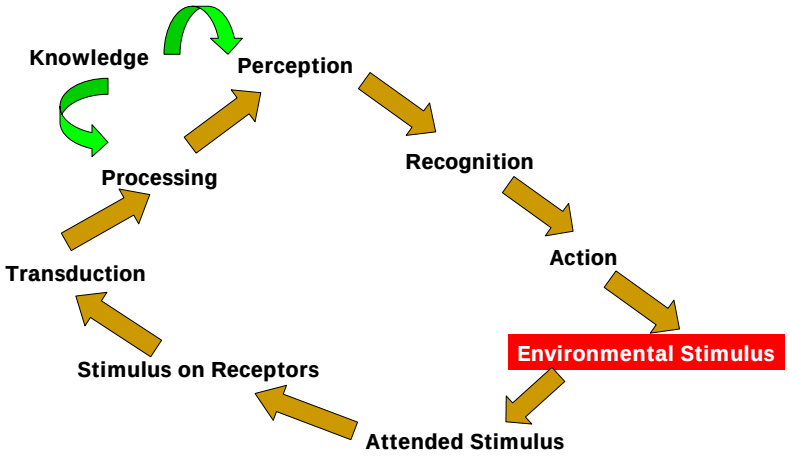
- Perceive
- Locate
- Identify/Recognize
  - Different objects
  - Their relationship with each other
    - Qualitative and Quantitative
- Act based on these information

It is a miracle that we do not cause accidents/mistakes every now and then

Perceptual Process



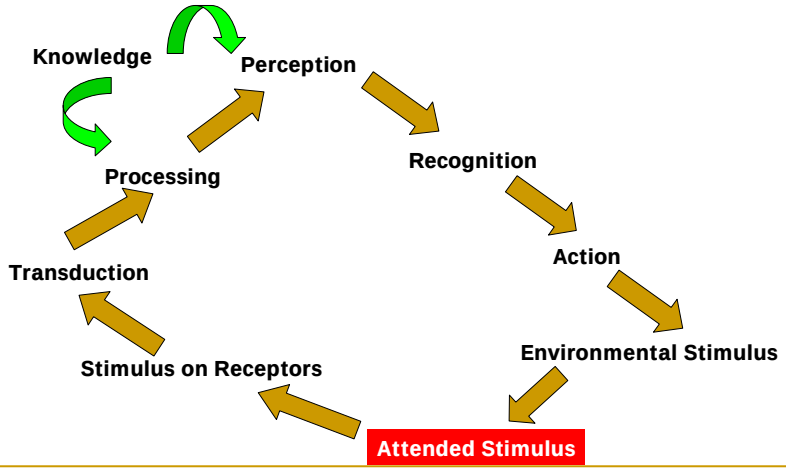
Perceptual Process



Environmental Stimulus

- Anything in our environment that we can perceive
- Can be anything we can sense
  - See, hear, touch, smell

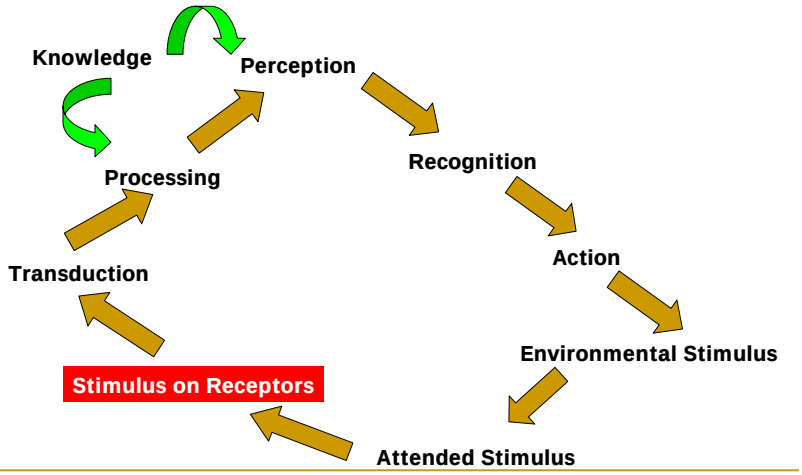
Perceptual Process



Attended Stimulus

- A part of the environmental stimulus
- Focuses attention on this stimulus

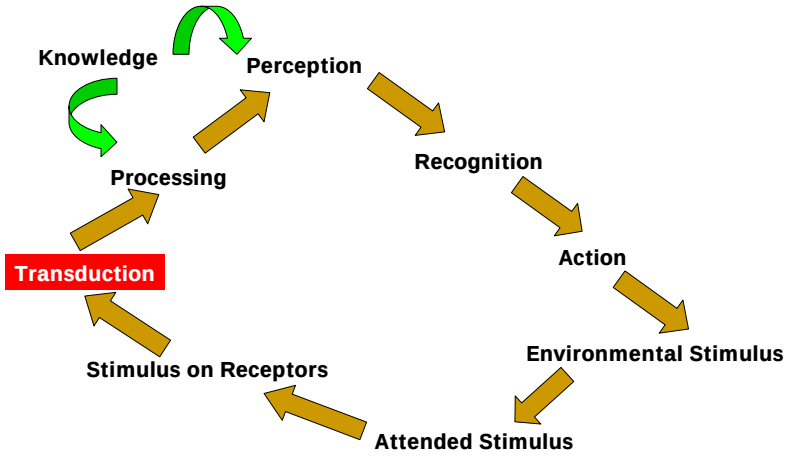
Perceptual Process



Stimulus on Receptors

- The attended stimuli excites the receptors
- For example
  - Visual stimulus forms a image on the retina
  - Sound changes pressure to affect the ear drum
- Note
  - We do not `perceive' the image on the retina
  - It is just one of the initial steps of the process

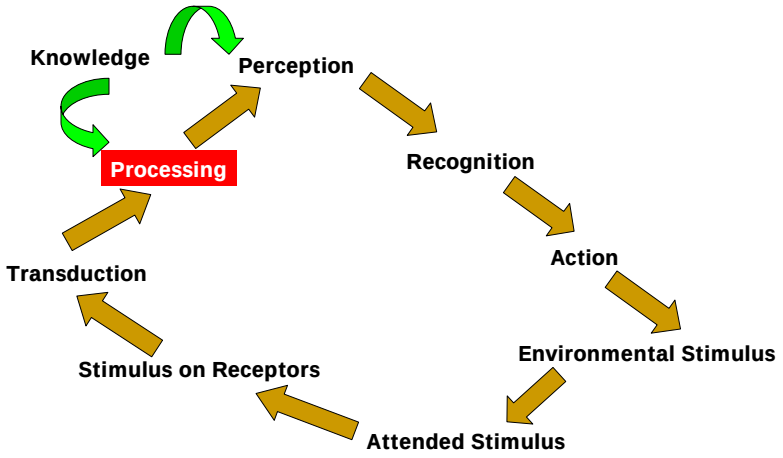
Perceptual Process



Transduction

- Transformation of one form of energy to other
- Environmental energy transformed to electrical energy
- The image on the retina generates electrical signals in the tens and thousands receptors of the eye

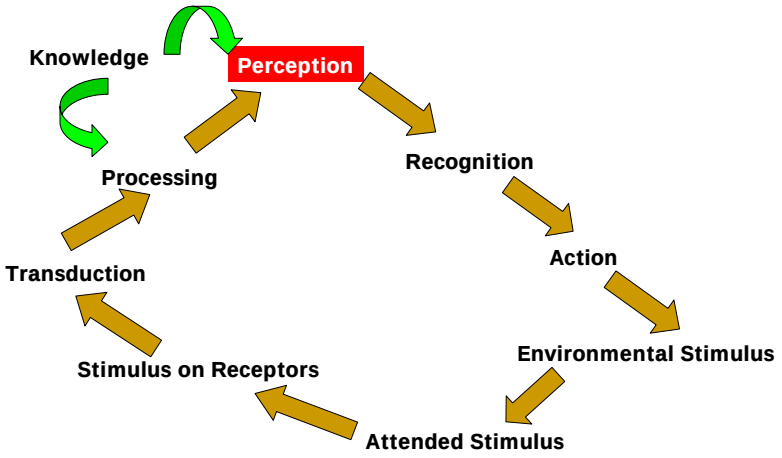
Perceptual Process



Neural Processing

- Neurons are elements of nervous system
- Interconnected together
- Processing of the electrical energy by the neurons while they travel through them
  - This changes the electrical energy in various ways

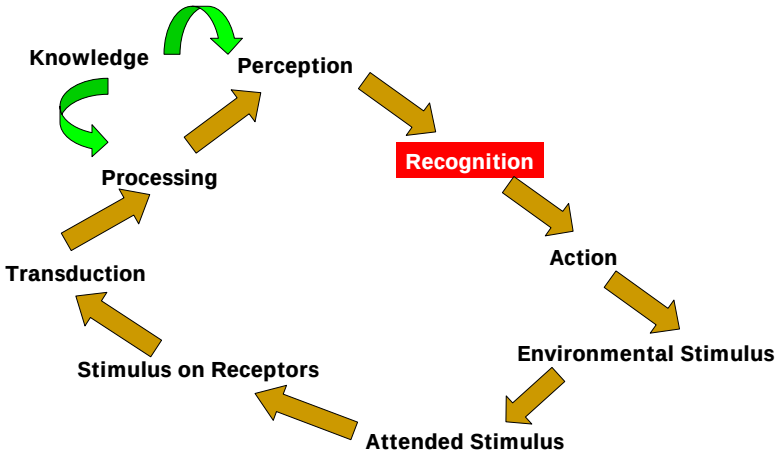
Perceptual Process



Perception

- Conscious sensory experience
- Electric energy transforms in brain to some experience
- Is this the end of perception?
  - Recognition and action are important outcomes of the perceptual process

Perceptual Process



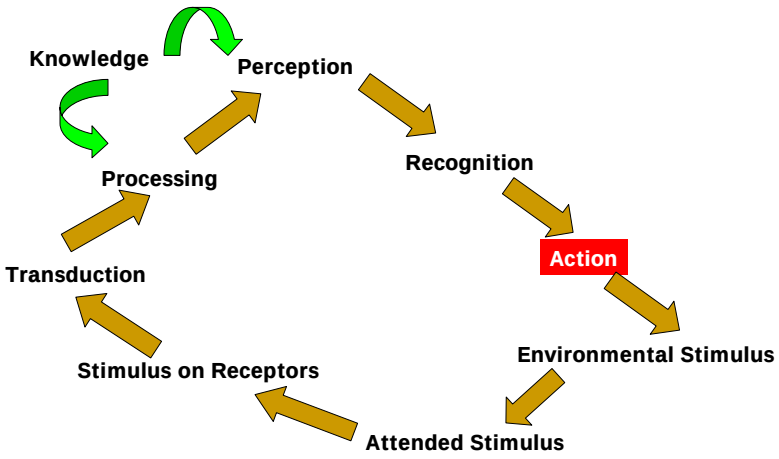
Recognition

- Identifying the experience as something
  - Known
  - Similar to some experience before
- Recognition and Perception are two separate process
- *The Man who Mistook his Wife for a Hat*
  - *By Oliver Sacks*

Visual form of agnosia

- Dr. P found he cannot recognize students but can tell their name from their voices
- Started conversation with parking meters or expected furniture to talk to him
- Was he blind?
  - Eye examination showed no problem
- Inability to recognize objects due to a tumor in brain
- When show a gloves, he told
  - *a continuous surface, unfolded by itself, with five outpouchings*
  - *Maybe a container or a purse to keep coins to different sizes*
- He can **perceive** an object, identify parts of it, but cannot assemble the parts **perceptually** to recognize it

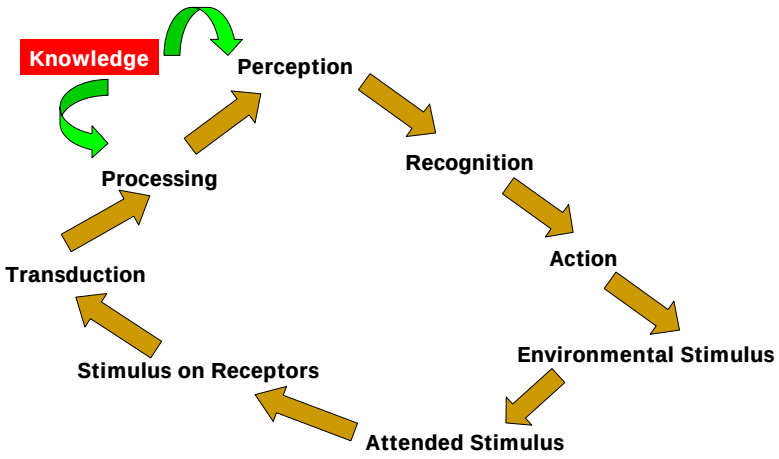
Perceptual Process



Action

- Goal of perception is to create action
  - Evolutionary reason for development of perception
- Motor activities
- Response to perception and recognition
- Leads to
  - New attended stimulus
  - Whole cycle repeats

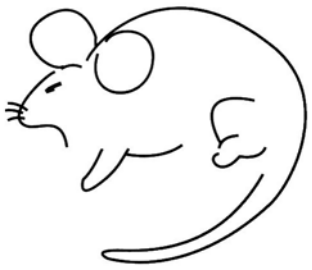
Perceptual Process



Knowledge

- Affects
  - Processing, Perception, Recognition
- Identification from memory
  - Old knowledge
  - Recent knowledge

Cognitive Influences on Perception



Cognitive Influences on Perception

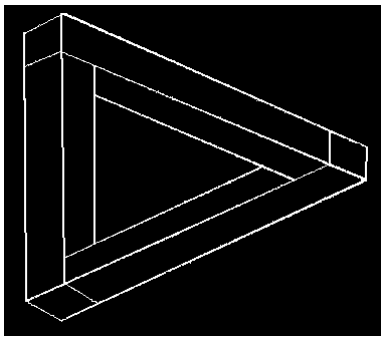
Visual Perception

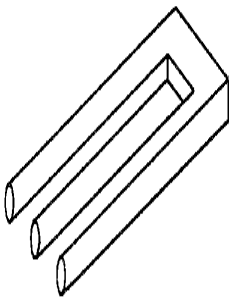
- Vision plays preeminent role for humans
- Evolutionary history
  - Vision was developed to aid survival and successful reproduction
    - Used to get nourishing food, safe shelter and strong mates
    - Also avoid dangers and predators

Why Vision is so Important?

- Vision is preeminent
- Only sense that provides accurate spatial information from a distance
  - Smell and hearing provides information from a distance but not accurate
  - Touch and taste provide very accurate information but only on contact
- Vision helps us most to keep away from danger
- Vision is a veridical perception
  - *What you see is what you get*

Pathological Cases





Studying Perceptual Process

- Levels of Analysis (At different scales)
- Bottom Up
  - Starting from the stimulus towards perception
- Top Down
  - Starting from knowledge
- We will study both and cross refer

Studying Perceptual Process

- Psychophysical
  - Relationship between stimulus and perception
  - What?
- Physiological
  - Relationship between the processes within a person and perception
  - How?

Psychophysical Approach

- Description
- Recognition
- Detection
- Magnitude
- Search

Psychophysical Approach

- Description
  - Describing the experience
  - Phenomenological Method

Recognition

- A stimulus is presented, the subject has to recognize it
  - Widely used by physicians and doctors
  - Usually qualitative

Detection

- Absolute threshold
  - Smallest amount of stimulus required to generate detectable perception
- Difference threshold
  - Smallest difference between two stimulus that a person can detect
- Sensitivity = 1/threshold
- *Classical Psychophysical Methods*
  - *Elements of Psychophysics by Fechner*

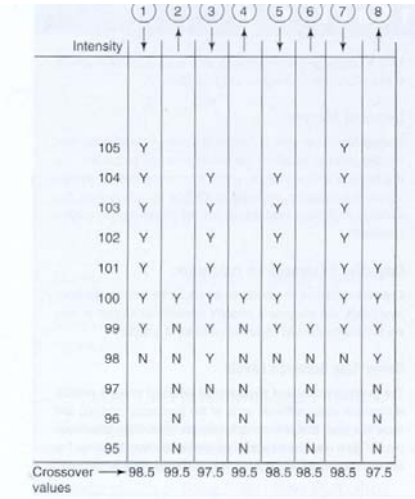
Absolute threshold

- Measured by
  - Method of limits
  - Method of adjustment
  - Method of constant stimuli

Absolute threshold

- Measured by
  - Method of limits
    - Presents stimuli in ascending or descending order
  - Method of adjustment
  - Method of constant stimuli

Method of Limits



Intensity	1 ↓	2 ↑	3 ↓	4 ↑	5 ↓	6 ↑	7 ↓	8 ↑
105	Y						Y	
104	Y		Y		Y		Y	
103	Y		Y		Y		Y	
102	Y		Y		Y		Y	
101	Y		Y		Y		Y	Y
100	Y	Y	Y	Y	Y		Y	Y
99	Y	N	Y	N	Y	Y	Y	Y
98	N	N	Y	N	N	N	N	Y
97		N	N	N		N		N
96		N		N		N		N
95		N		N		N		N
Crossover values →	98.5	99.5	97.5	99.5	98.5	98.5	98.5	97.5

Results of using method of limits

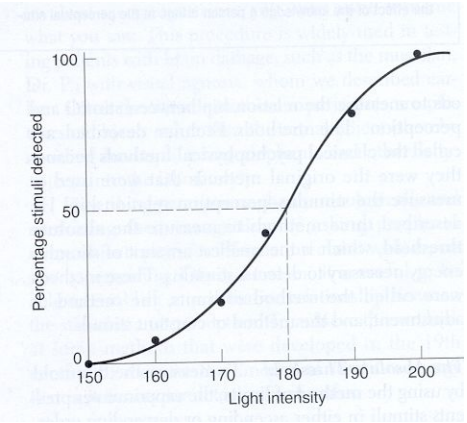
Absolute threshold

- Measured by
  - Method of limits
    - Presents stimuli in ascending or descending order
  - Method of adjustment
    - Subject controls the strength of stimulus
  - Method of constant stimuli

Absolute threshold

- Measured by
  - Method of limits
    - Presents stimuli in ascending or descending order
  - Method of adjustment
    - Subject controls the strength of stimulus
  - Method of constant stimuli
    - Presents stimuli of random strength in random order

Method of Constant Stimuli



Measuring Absolute Threshold

- Method of limits and adjustment
  - Errors due to anticipation
  - Fast
- Methods of constant stimuli
  - Most reliable
  - Slow

Difference Threshold

- ‘Standard weight’ compared with `comparison weight’
- The `comparison weight’ is increased from ‘standard weight’ unless the change is detected
- The detectable change is a function of the `standard weight’

Weber Law

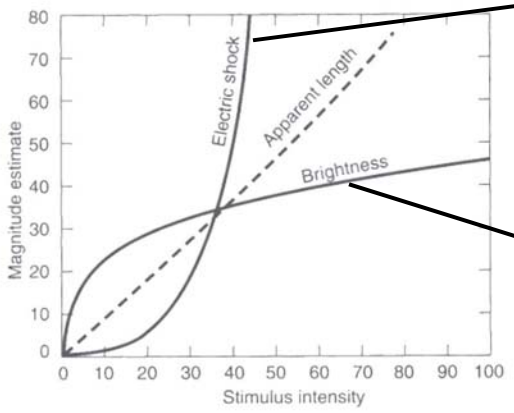
$$\frac{\text{Difference Threshold}}{\text{Standard Weight}} = K$$

K: Weber fraction

Magnitude

- Threshold measures detectable changes
- How to measure what happens once we are past the threshold?
- Magnitude Estimation
  - Present subjects with different strength of stimuli at random
  - Ask them to number the strength of perception
  - Plot these to estimate the magnitude

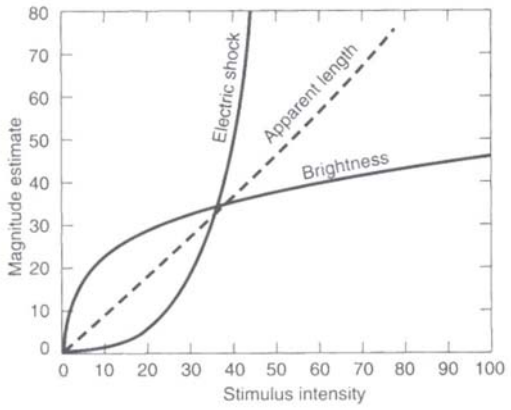
Response



Response Expansion

Response Compression

Steven's Power Law



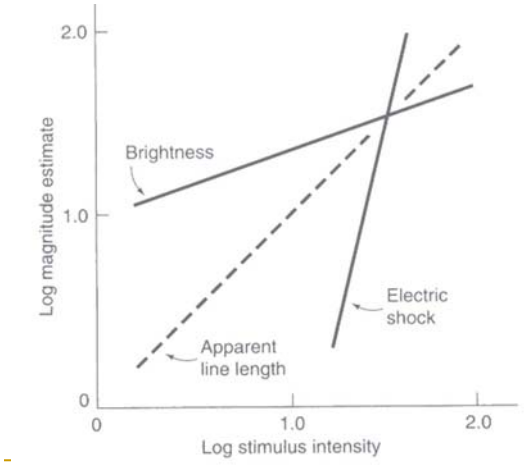
$P = KS^n$

P = Perception
S = Stimulus Strength

n>1.0 (Expansion)

n<1.0 (Compression)

Steven's Power Law



$P = KS^n$

P = Perception
S = Stimulus Strength

n>1.0 (Expansion)

n<1.0 (Compression)

Adapted to Functions of Organisms

- Bright sunlight would not appear very bright since n=0.6
- If n>1.0
  - Brightness of outdoor scenes would not allow us to see anything inside
  - May even impair our ability to see

Adapted to Functions of Organisms

- For electric shock, small changes cause large perception of pain
- Acts as a warning mechanism
- So that we can react before much damage is done

Searching

- Can be easy if objects stand out
- Difficult if they mingle well with their surrounding

Physiological Approach

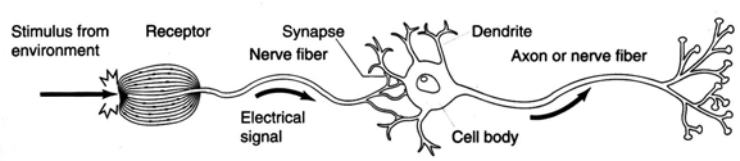
- Sensors have receptors that transduce environmental energy to electrical enery
- Nerves carry these signals to the brain
- Processing in brain leads to the experience of perception

Intrigued people for a long time ….

- In mid 19th century by Johannes Mueller
  - Showed that electrical energy flows down the nerve
  - Can measure electrical signals in brain to assure brain activity
  - Nature of perception depended on which nerves were stimulated
  - Quality of perception depended on how these nerves were stimulated

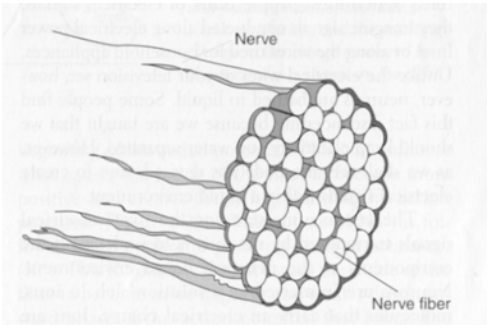
Neurons

- Neuron: Basic element of the nervous system
- Three parts of a neuron
  - Cell Body: Has the elements to keep it alive
  - Dendrites: Branches out from cell body to *receive* signals from other neurons
  - Axon: Tube filled with fluid that *conducts* the electrical signals



Nerve

- The nerve is formed by a bunch of axons



Perception

- Recording of electrical signal in receptors
- Transmission of signals to the brain
  - Some low level processing occurs at this time
- Processing in brain

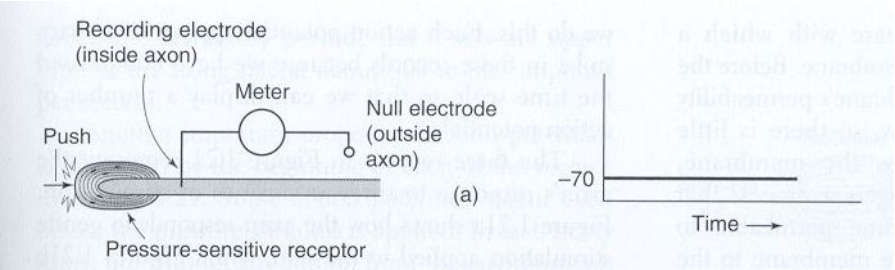
Receptor Neuron

- This is a special type of a neuron present in sensors
- Have a receptor (transducer) in place of a cell body

Recording the Electrical Signal

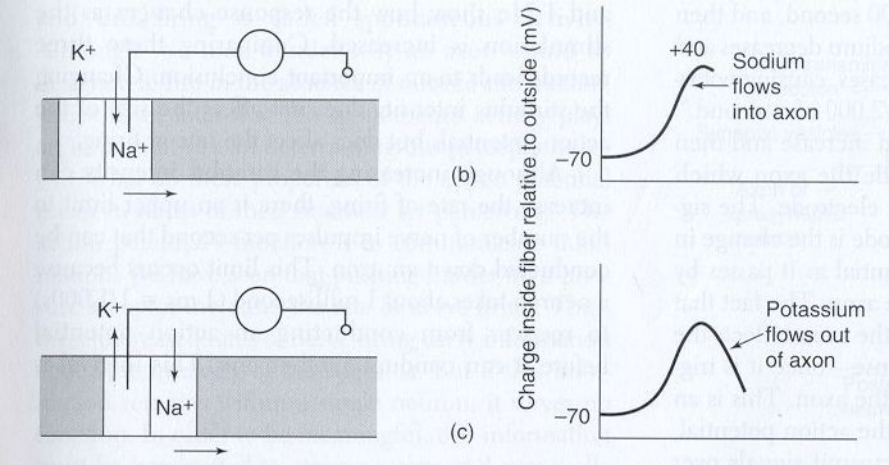
- At the receptor
- Electricity is not carried in the nerves as electricity is carried to our home
- Neurons are immersed in solutions rich in *ions* (molecules carrying electrical charge)
- The solution outside the axon is rich is Na^+
- The solution inside the axon is rich is K^+

Resting Potential

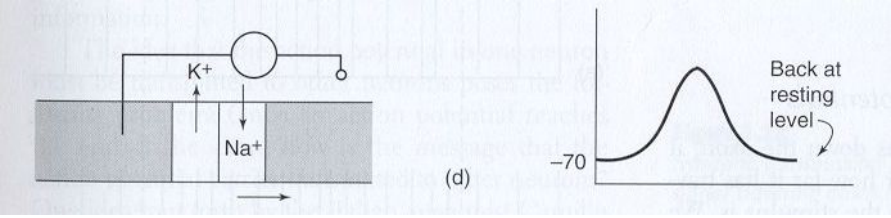


At normal state, the difference of charge is *-70 mV*

Action Potential (Nerve Impulse)



Back to Resting Potential



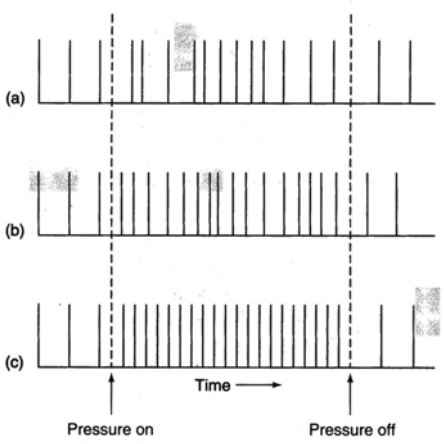
Sodium and potassium ion concentration goes back to normal by a process called sodium-potassium pump

How is it caused?

- Change in the permeability of the axon membrane
- Before stimulus, the permeability to sodium and potassium is low
- The receptor when excited triggers a process which increases this permeability
- Everything happens in *1ms*
- Propagated response: This action potential travels through the axon

Strength of Signal

- Action potential magnitude is always same
- How is strength of stimulus denoted?
  - Rate of firing



Rate of Firing

- After every firing there is a *refractory period* of *1ms*
- This limits the maximum firing rate to a maximum of 800 pulses per second
- In the normal state, there is some firing called *spontaneous activity*

Transmission of Electrical Signals

- From one neuron to another
  - End of axon of one neuron to dendrite of another
- No physical contact between neurons
- Synapse: Small space between neurons
  - Discovered by Spanish anatomist Santiago Ramon Cajal
  - Won Noble Prize for this in 1906

Synapse

- Electrical signal triggers a chemical process in the synapse that is instrumental in transmitting the signals
- Presynaptic Neuron: From whom the signal is transmitted
- Postsynaptic Neuron: The one who is receiving the signal

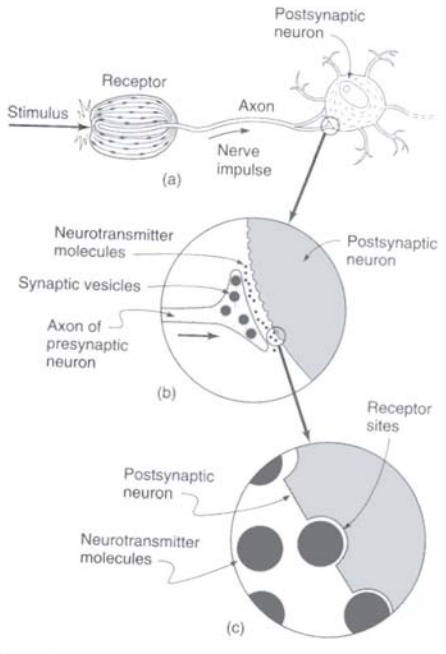
Synapse

- Axons of neurons have *synaptic vesicles* that can release *neurotransmitters*
  - Neurotransmitters can be of different shapes
- Dendrites of neurons have *receptor sites*
  - Receptor sites can be of different shapes too

Synapse

- When electrical energy reaches the end of presynaptic neuron
  - Releases the neurotransmitters
- If the shape matches the receptor site in postsynaptic neuron
  - Generates electric energy again
- Transmission is controlled by the type of neurotransmitters generated

Synapse



Synapse

- Electrical signals transmitted may not be identical to the presynaptic neuron
- Can be *excitation* or *inhibition*
- Low level processing while transmission

Brain

- Cerebral Cortex
  - 2mm thick layer that covers the surface of the brain
  - Used for perception, language, memory and thinking
- Modular organization

Brain

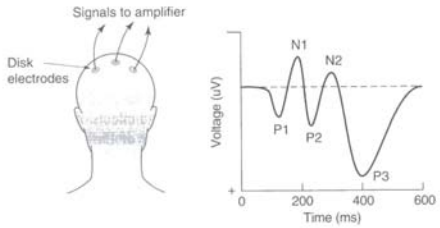
- Primary Receiving Areas
  - First areas in Cerebral Cortex to receive the signals
  - Occipetal lobe: For eye
  - Temporal lobe: For ear
  - Parietal lobe:For skin
- Advanced processing
  - Involves other areas of the brain too

Studying Brain Activity

- Neuropsychology
  - Studying the effects of brain damage on behavior
- Microelectrodes on cats and monkeys
  - Intrusive

Studying Brain Activity

- Now can study on humans by less intrusive disk electrodes
  - Can study *evoked potentials*
  - Record activity of thousands of neurons

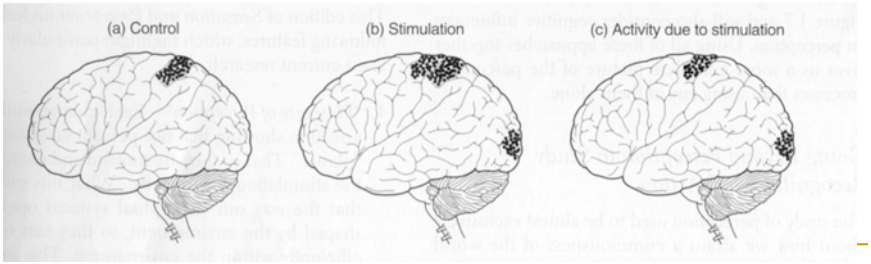


Neuroimaging

- Using positron emission tomography (PET)
- Person is injected with low activity radioactive tracer (not harmful)
- This tracer indicates volume of blood flow
- Basic concept:
  - Activity in brain is accompanies with changes in the volume of blood flow
  - Monitoring blood flow

Subtraction technique

- Find state before stimulus
- Find state after stimulus
- Difference gives what was cause by stimulus



Functional Magnetic Resonance Imaging (fMRI)

- Hemoglobin has iron
- If presented with magnetic field, they line up like tiny magnets to indicate volume of blood flow
- Especially, with activity hemoglobin loses some of it oxygen making it more magnetic
- Popularly called *Brain Scan*

THE END