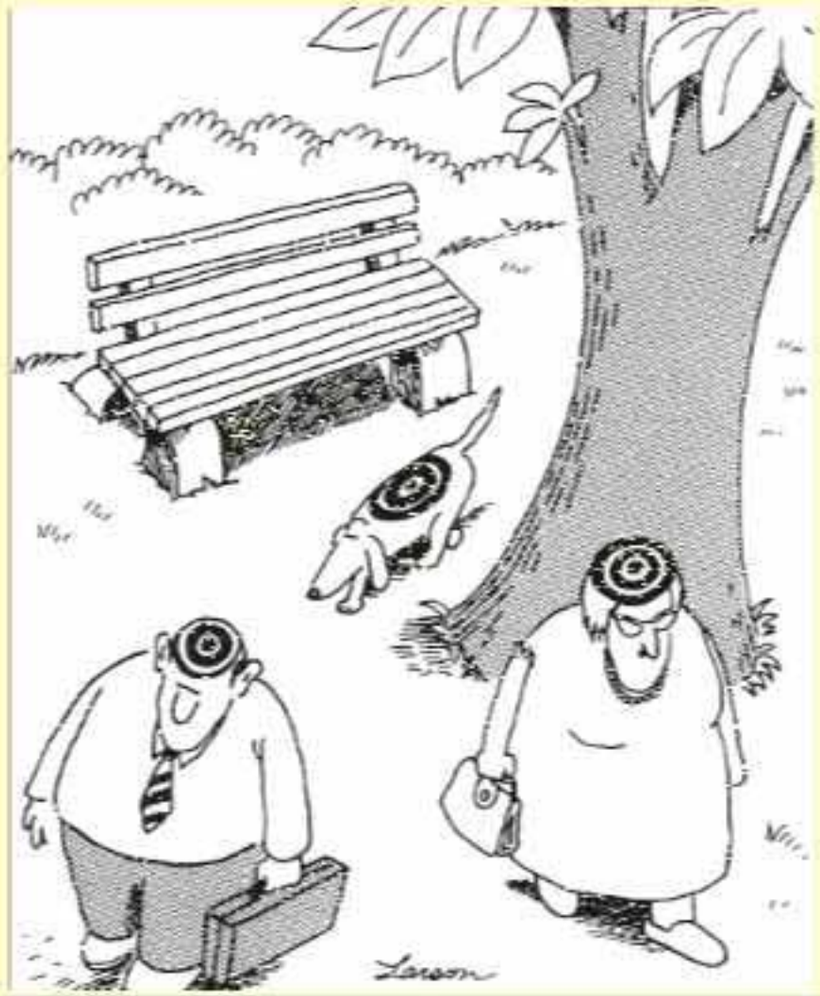
Animal senses: how do they perceive the world and what important things can they sense that we cannot ?



How birds see the world

Animal senses: how do they perceive the world and what important things can they sense that we cannot ?

- How we and other species experience the world around us

- How we recognise each other

- Our respective capacities for self-awareness

Animal senses: how do they perceive the world and what important things can they sense that we cannot ?

- Senses merely provide an interpretation of the outside world

- Subjective but comforting illusion of an absolute reality

- The external world can be experienced in many different ways

Each species has evolved its senses to survive by interacting successfully with the environment

- Only humans have developed sophisticated artificial sensors to detect environmental signals beyond those immediately required for survival

- In most cases examples of these artificial sensors have biological-based equivalents in other species

The five primary senses

- Touch

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The five primary senses

- Touch

- Taste

-

-

-

The five primary senses

- Touch

- Taste

- Smell

-

-

"I want my husband to pay more attention to me. Got any perfume that smells like a computer?"

The five primary senses

- Touch
- Taste
- Smell
- Hearing
-

The five primary senses

- Touch

- Taste







- Smell

- Hearing

- Sight

Others

- Balance

-

-

-

-

Others

- Balance

-

-

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-

Others

- Balance

- Magnetic fields

-

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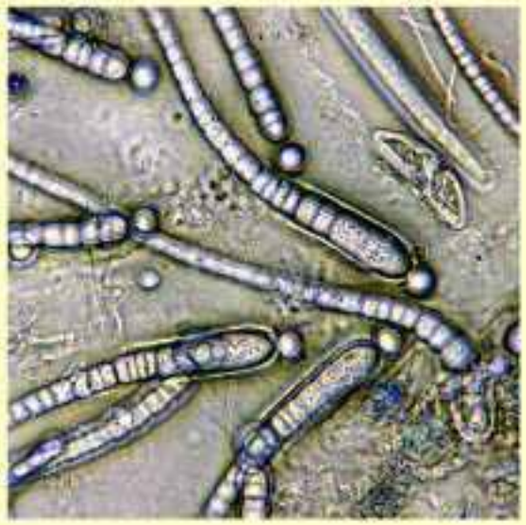
-



Others

- Balance

- Magnetic fields

-

-

Others

- Balance

- Magnetic fields

-

-

-

Others

- Balance

- Magnetic fields

- Electrical fields

-

-

-

Others

- Balance

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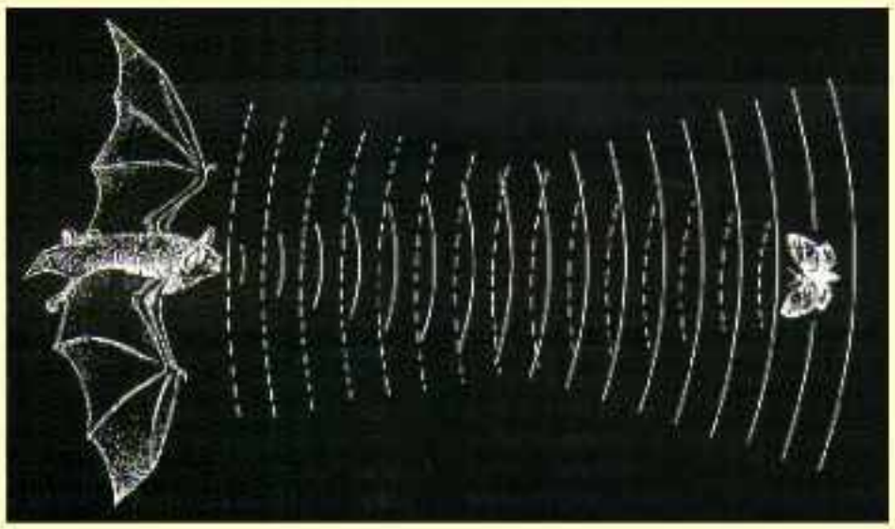
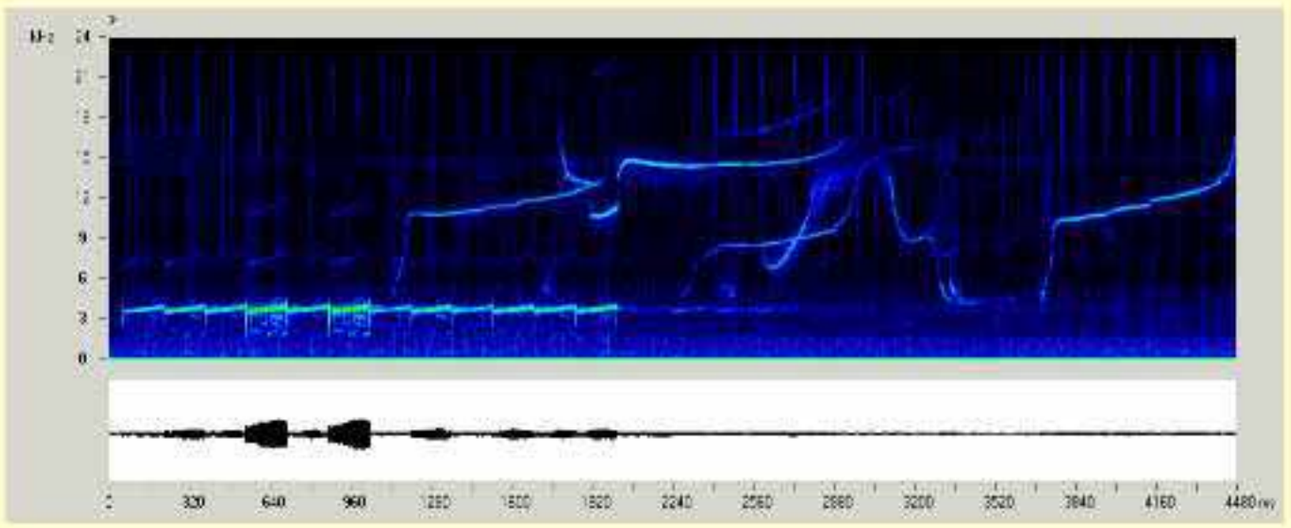
- Electrical fields

- Biosonar

-





Others

- Balance

- Magnetic fields

- Electrical fields

- Biosonar

- Telepathy

Others

- Balance

- Magnetic fields

- Electrical fields

- Biosonar

- Telepathy

Some special 'sensory' abilities claimed for other animal species:

- Knowing when their owners or companions intend to return

-

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Some special 'sensory' abilities claimed for other animal species:

- Knowing when their owners or companions intend to return

- Detecting illnesses such as cancer or warning owners of impending epileptic attacks or high blood pressure

- Detecting emotional states in others

- Detecting hormonal states in others

- Detecting the presence of buried objects

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Some special 'sensory' abilities claimed for other animal species:

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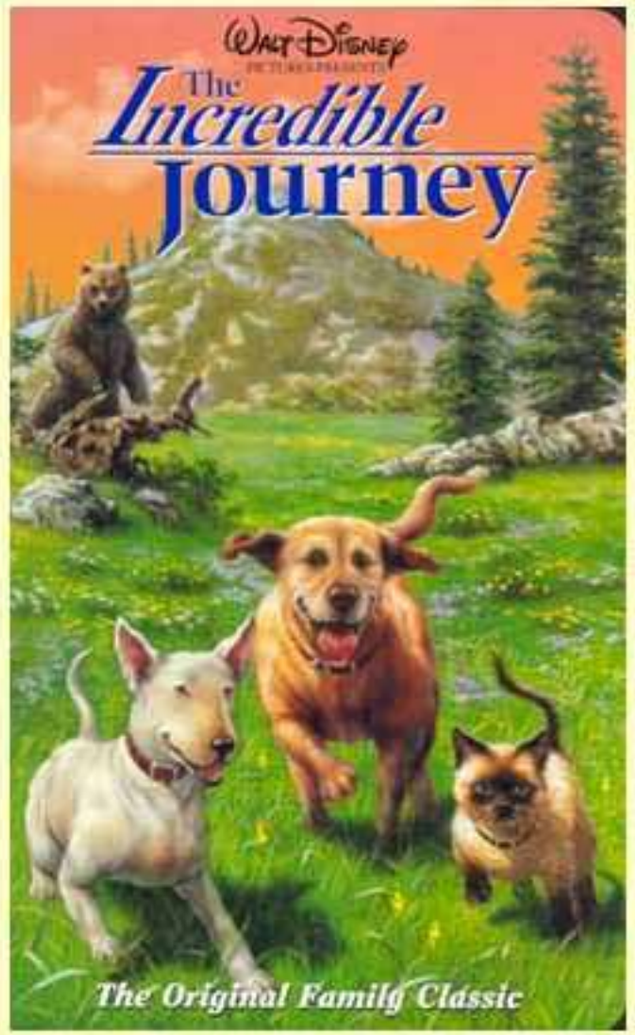
- Detecting the presence of buried objects

- Tracing owners or companions and making long journeys to be re-united



Some special 'sensory' abilities claimed for other animal species:

- Finding their way back home from great distances

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- Using sun compasses or reading celestial maps

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Some special 'sensory' abilities claimed for other animal species:

- Finding their way back home from great distances

- Detecting electromagnetic fields, ultrasonic frequencies or infrared and ultraviolet wavelengths

- Locating objects using sonar

- Using sun compasses or reading celestial maps

- Sensing impending storms, earthquakes etc

General principles of sensory systems
- Sensory receptors

- Chemoreceptors - smell and taste receptors

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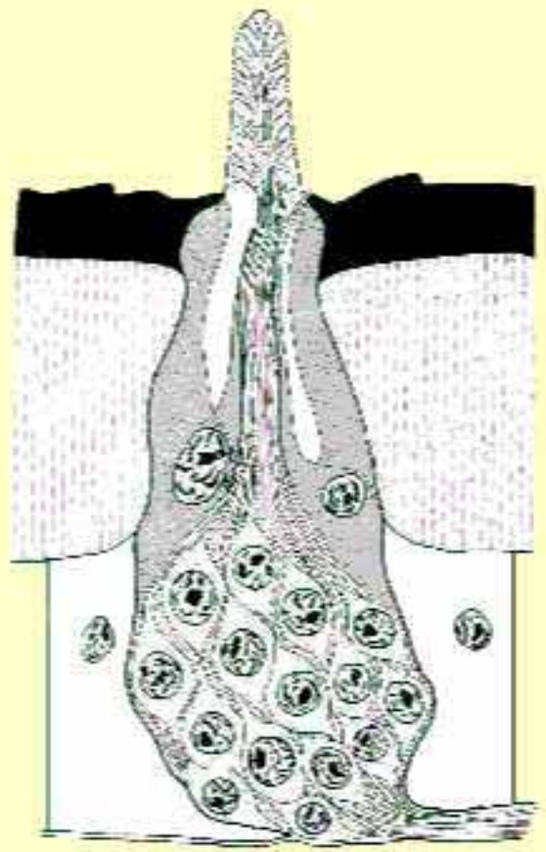

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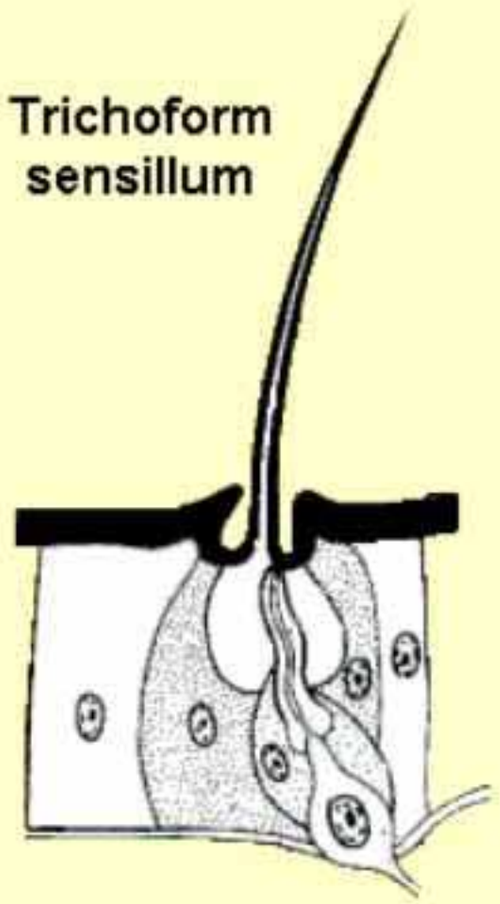

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- Nociceptors - to sense pain

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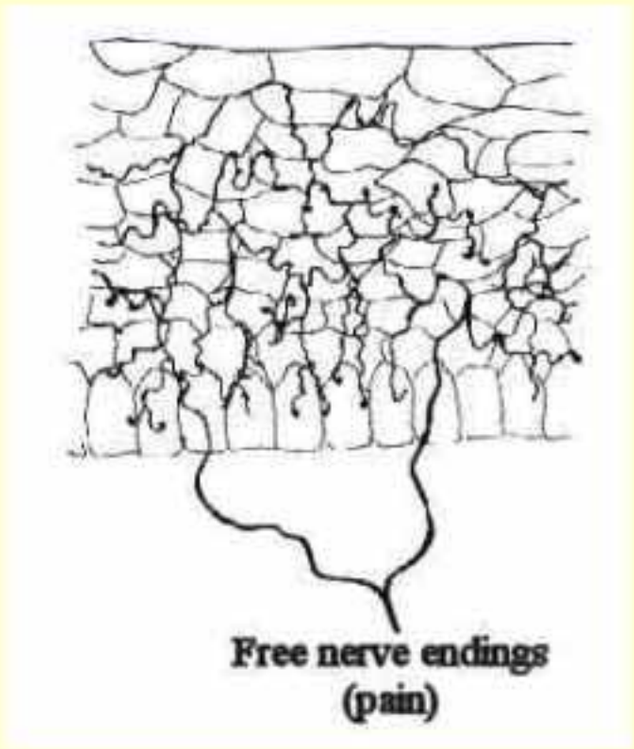

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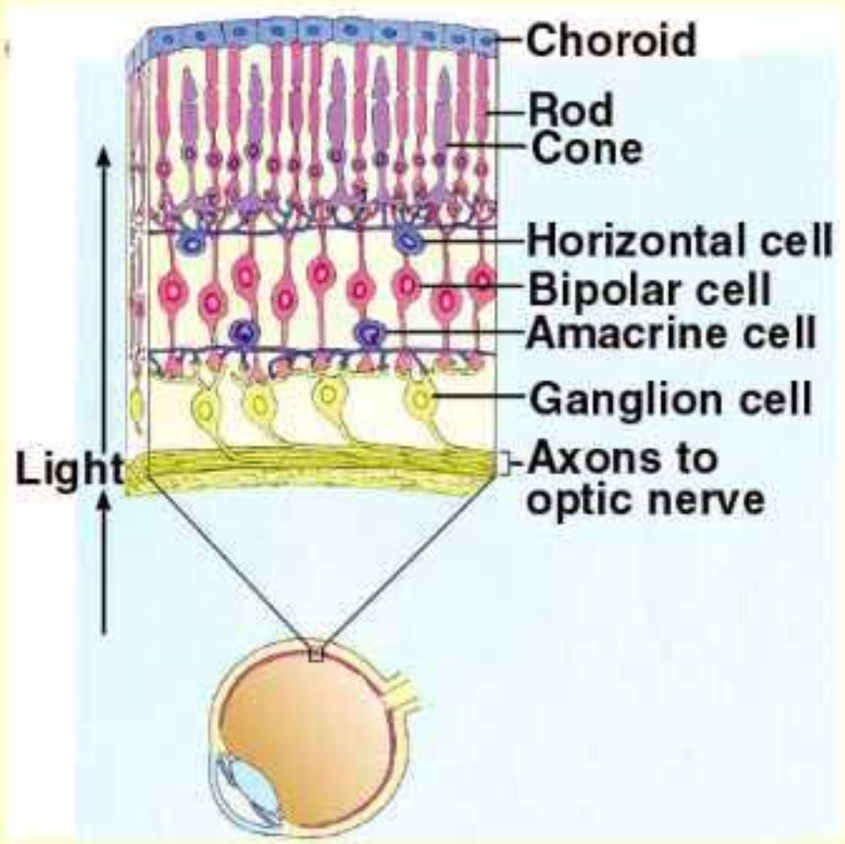

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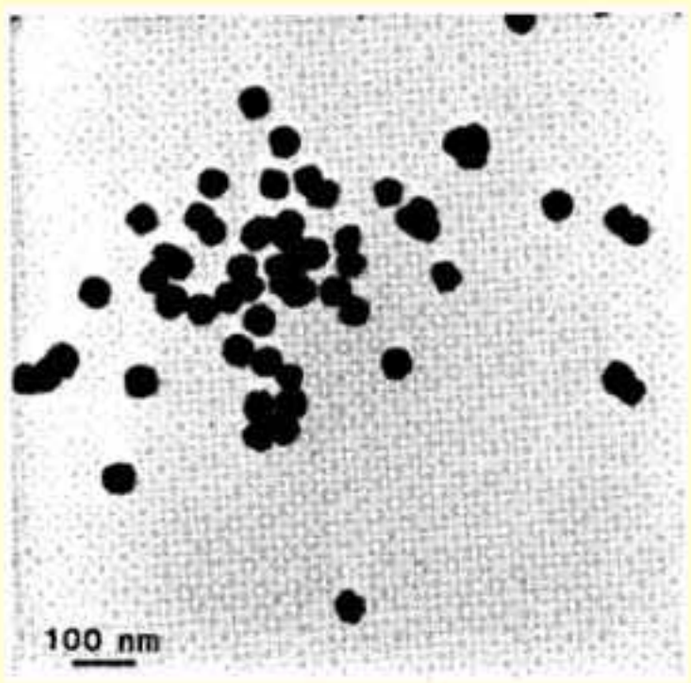
- Magnetoreceptors - to detect magnetic fields



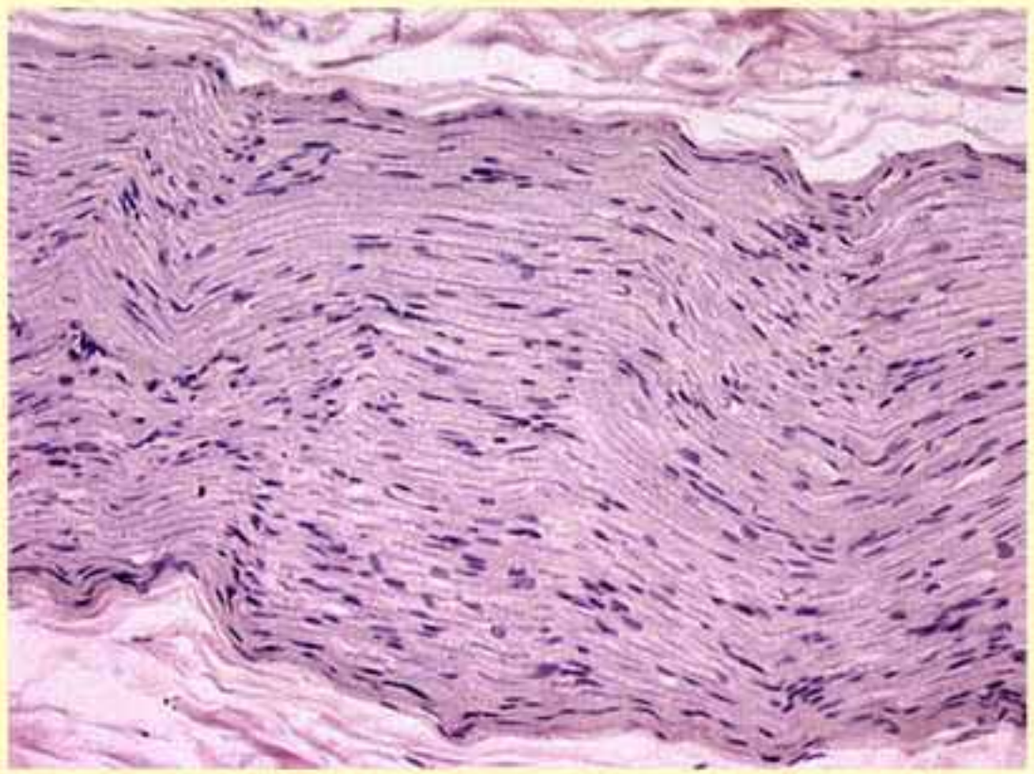
General principles of sensory systems
- Sensory receptors

- All transduce a specific form of energy into electrical impulses

- Greater sensitivity = more receptors

- Change is more important to detect than constancy

- Convey these to the brain via sensory nerves



General principles of sensory systems
- Sensory receptors

- The brain has a precise spatial and temporal map of the pattern of receptor activation

-

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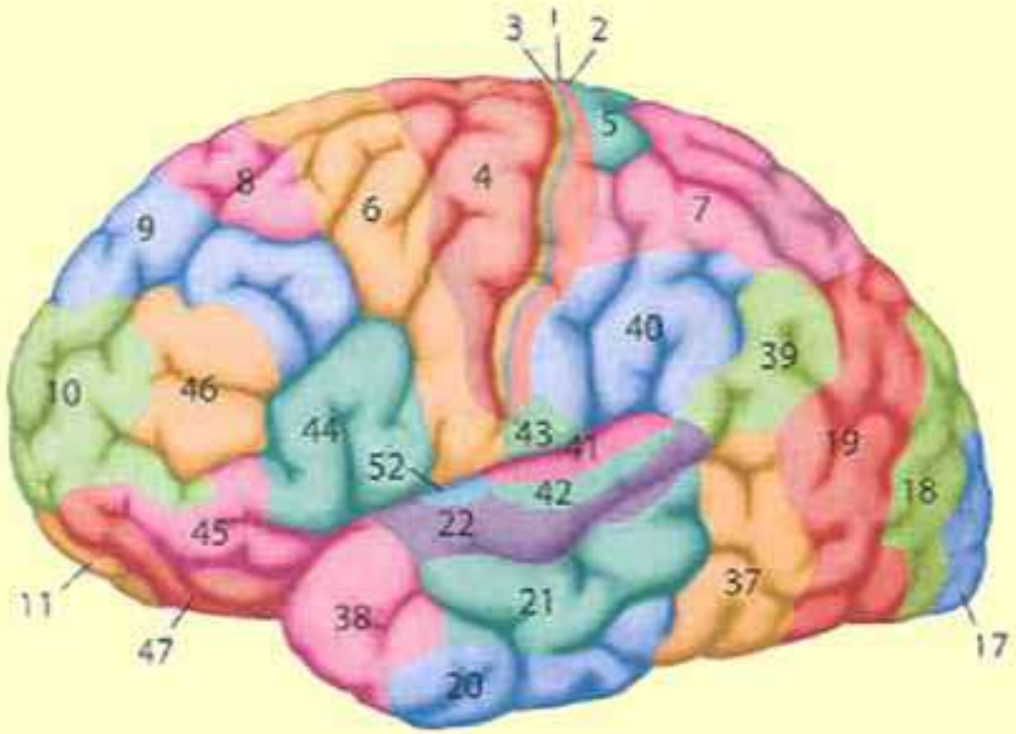

General principles of sensory systems
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- The brain has a precise spatial and temporal map of the pattern of receptor activation

- Each sensory modality is mapped onto a different part of the brain

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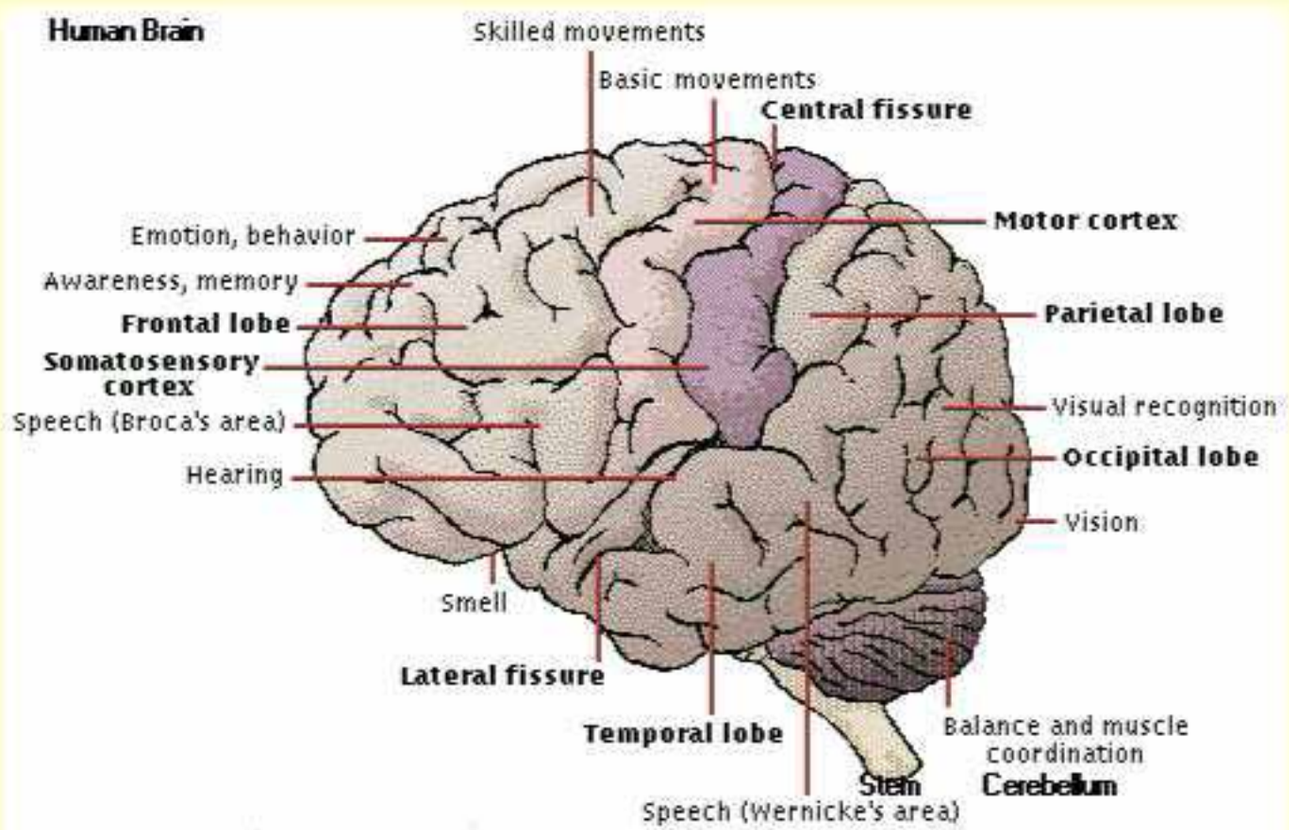


General principles of sensory systems
- Sensory receptors

- The brain has a precise spatial and temporal map of the pattern of receptor activation

- Each sensory modality is mapped onto a different part of the brain

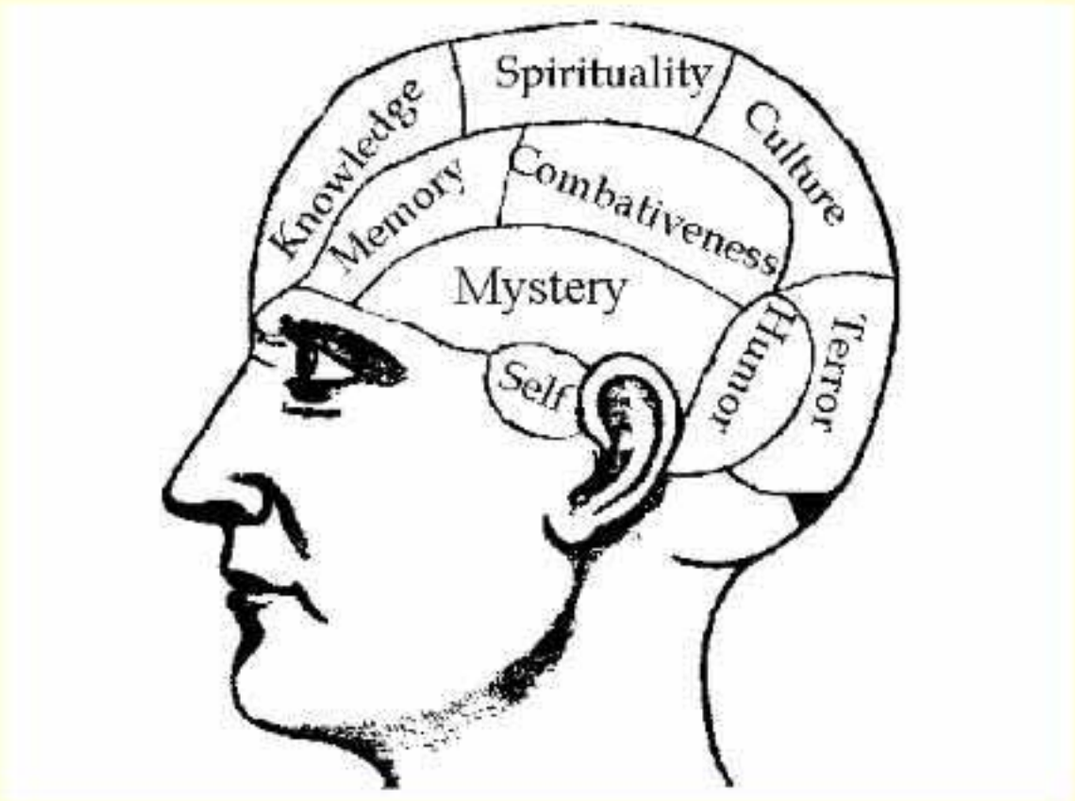
- Greater sensitivity associated with greater representation in the brain

General principles of sensory systems
- Sensory receptors

- Integration of the senses mainly occurs later in regions controlling memory and action

- Independent awareness of the world experienced through each sense ?

- Multiple independent illusory interpretations of reality ?



Touch

- The skin is our largest sensory system (50 square feet in humans)

- Different receptors for heat, cold, pain, itching and pressure

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- Body pressure receptors are mapped in somatosensory cortex

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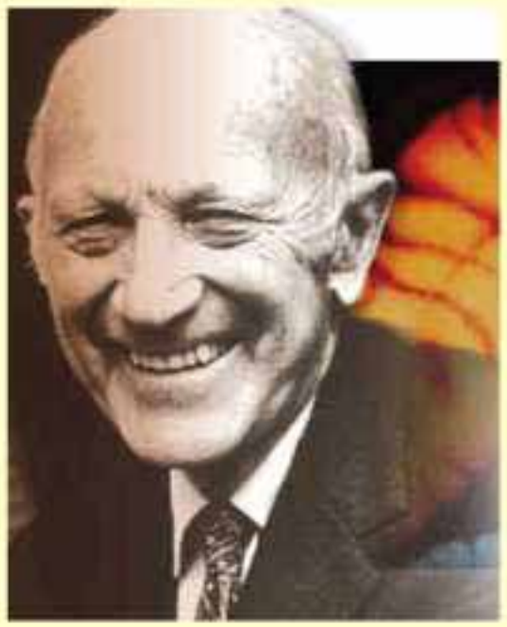


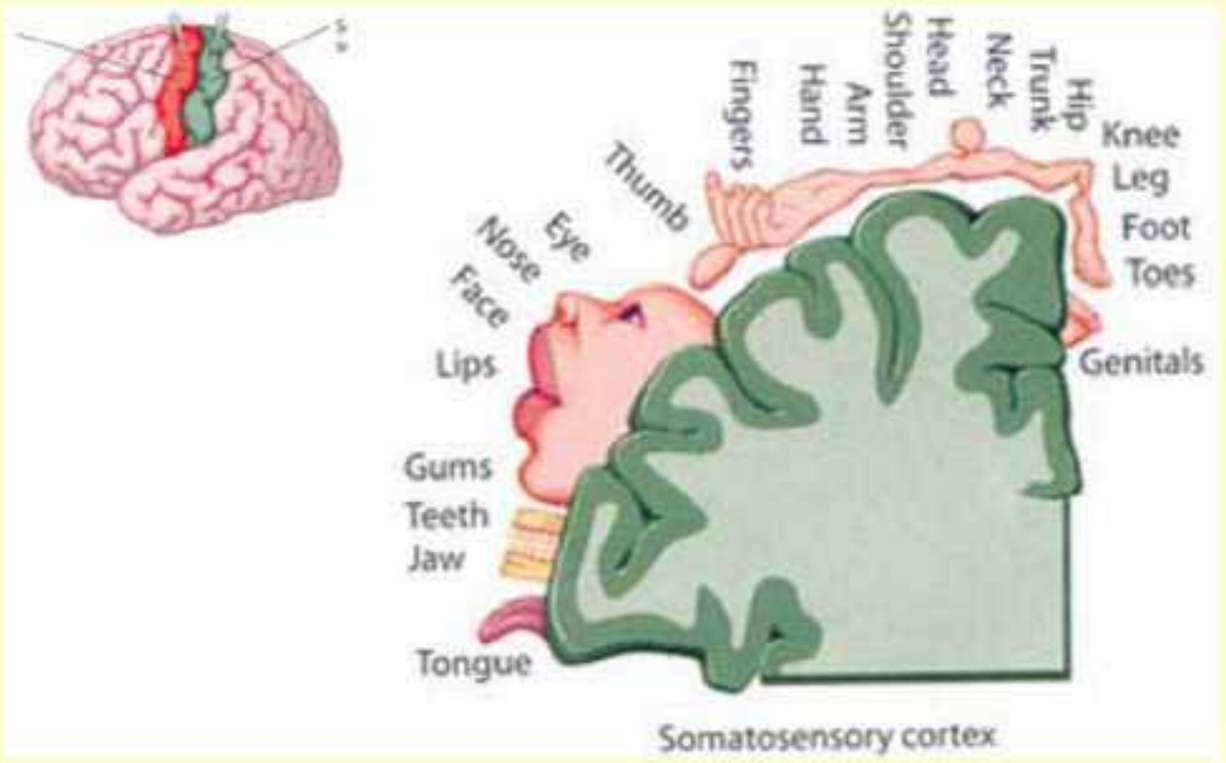
Touch

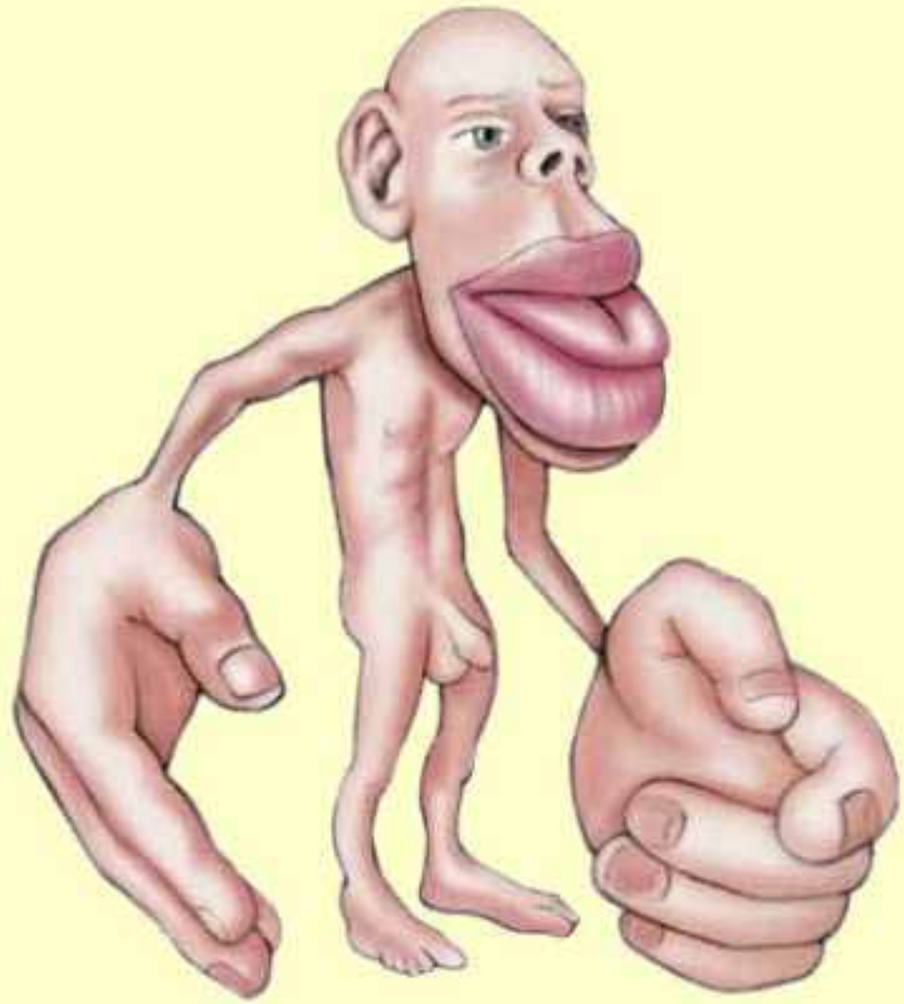
- The skin is our largest sensory system (50 square feet in humans)

- Different receptors for heat, cold, pain, itching and pressure

- Body pressure receptors are mapped in somatosensory cortex

- Somatotopic maps





Touch

- Experience can change the cortical representation

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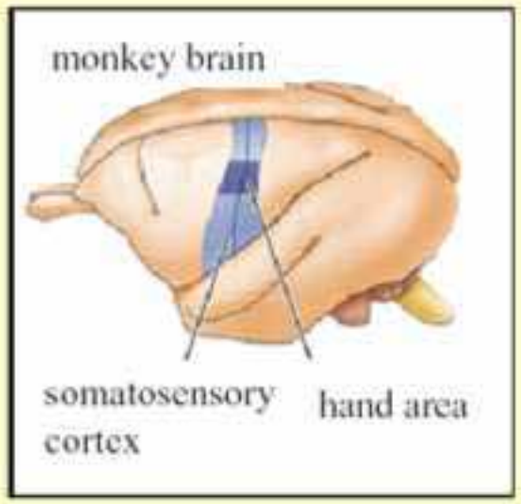
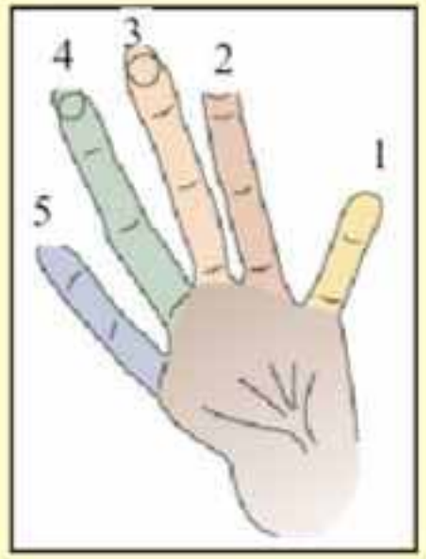
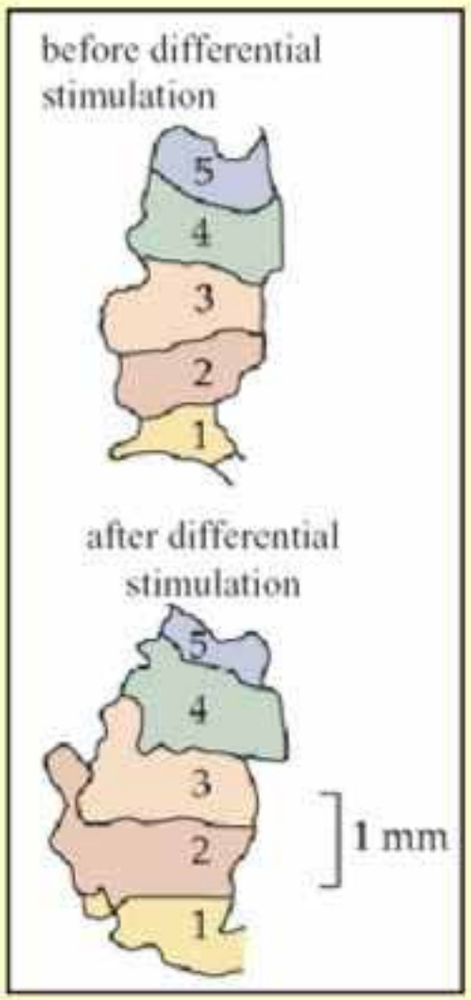






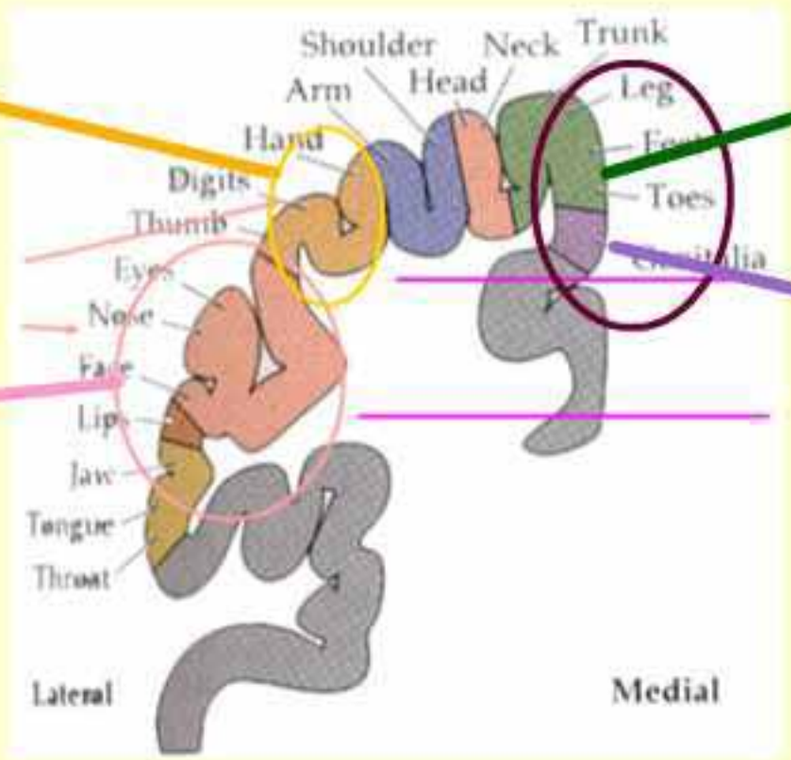
Touch

- Experience can change the cortical representation

- Experience of phantom limbs

Arm
Hand
Digits

Eyes
Nose
Face



Leg
Foot
Toes

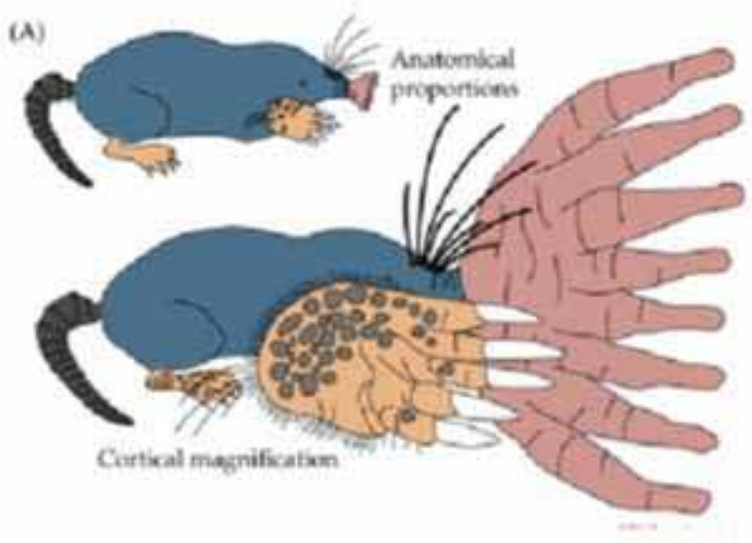
Genitalia

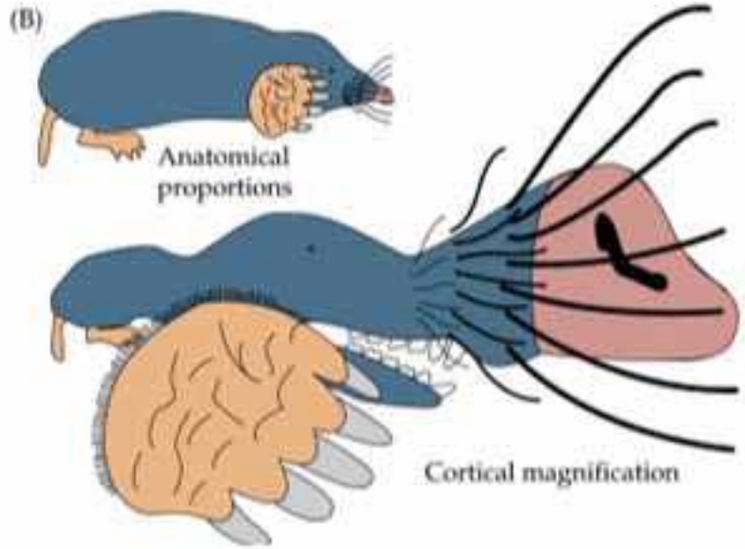
Touch
- Animals with enhanced touch sensitivity

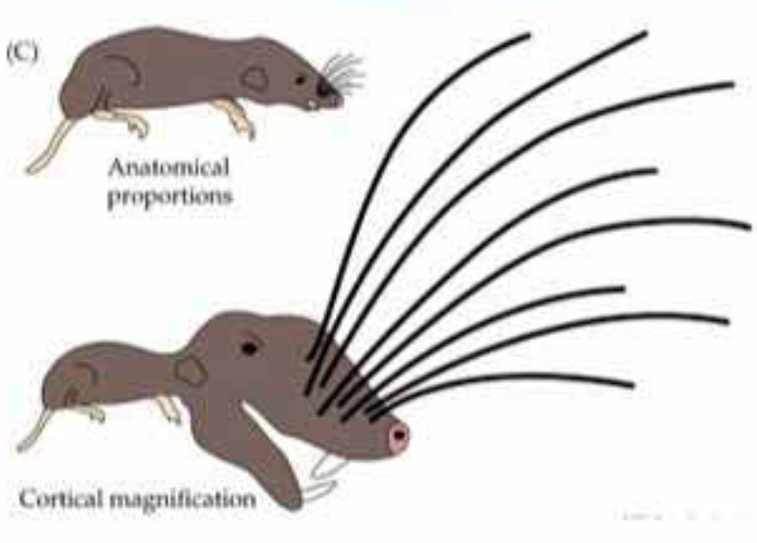
Star-nosed mole

Eastern mole

Masked shrew







Touch

- Animals with enhanced touch sensitivity

- The star-nosed mole has 100,000 touch receptors in the skin of its nose !

- Raccoons have very sensitive hands for helping to obtain food

- An enhanced sense of touch may help detect earth vibrations or changes in wind direction and velocity

- It is also likely to enhance sensitivity to pain

Smell and taste

- These senses are of paramount importance for survival in most mammals

- These chemical senses can work in combination (flavour perception)

- Chemical detection by sense of smell more sensitive than by taste

Taste

- Receptors on tongue, epiglottis and soft palate

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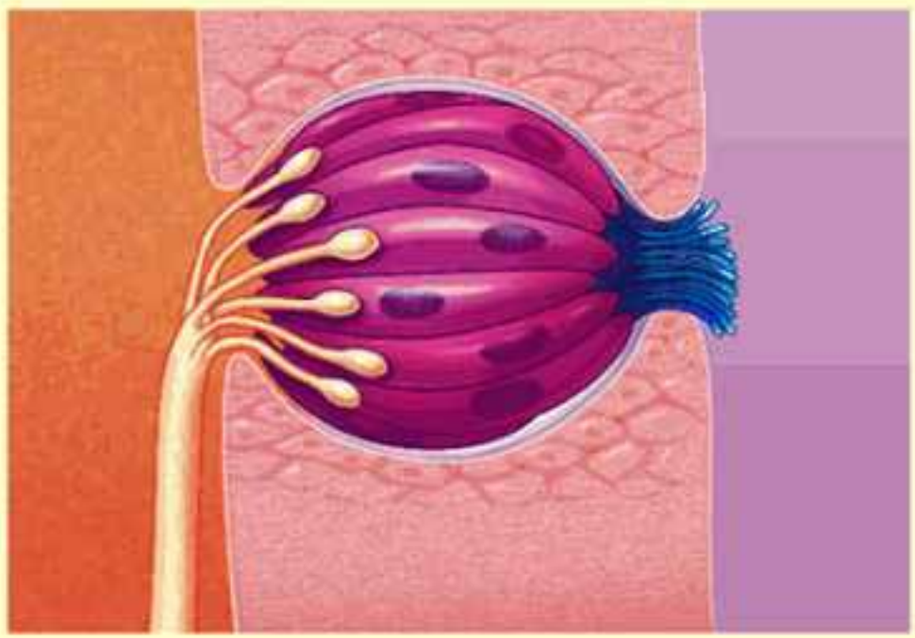


Taste

- Receptors on tongue, epiglottis and soft palate

- Salt - sodium

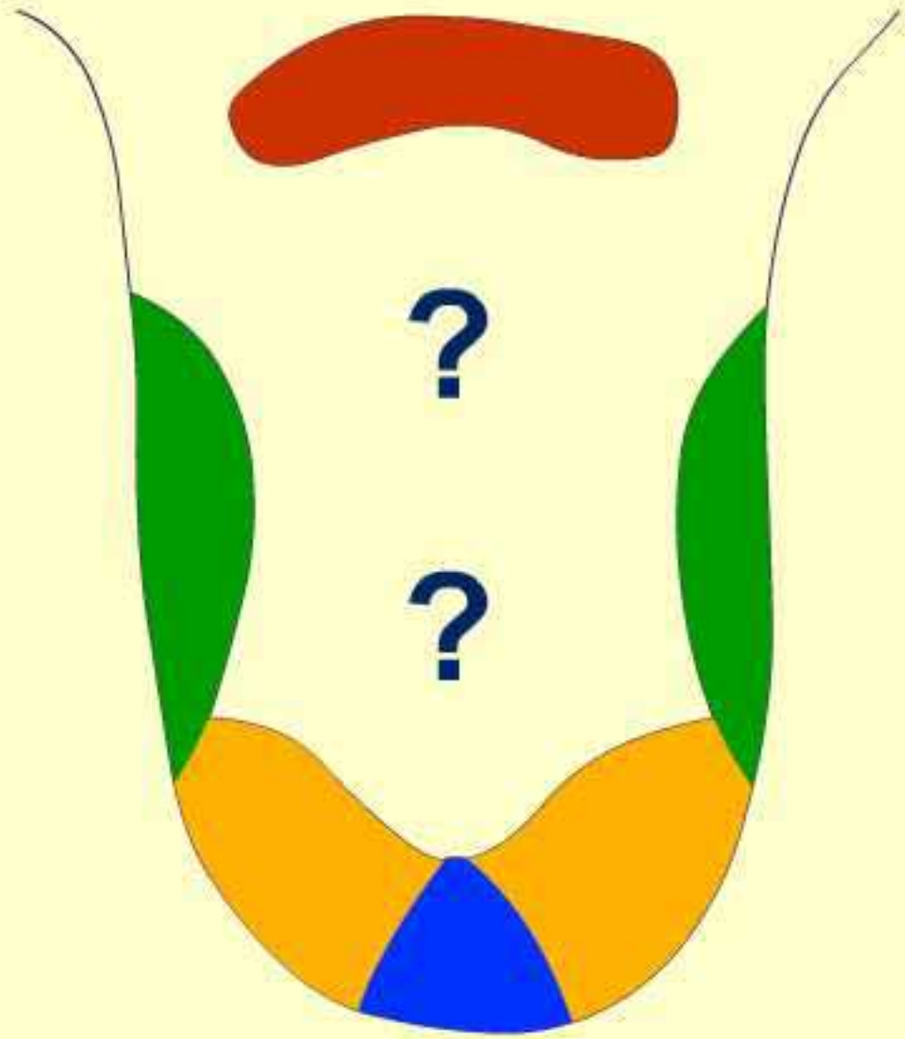
- Sweet - sugars

- Sour - acids

- Bitter - alkaloids

- Umami - monosodium glutamate and meat-like tastes

- Fat



The 'classic' taste map

Taste

Salt

Sweet

Sour

Bitter

Umami

Taste

- The system is biased towards detecting poisons (bitter and sour)

-

-

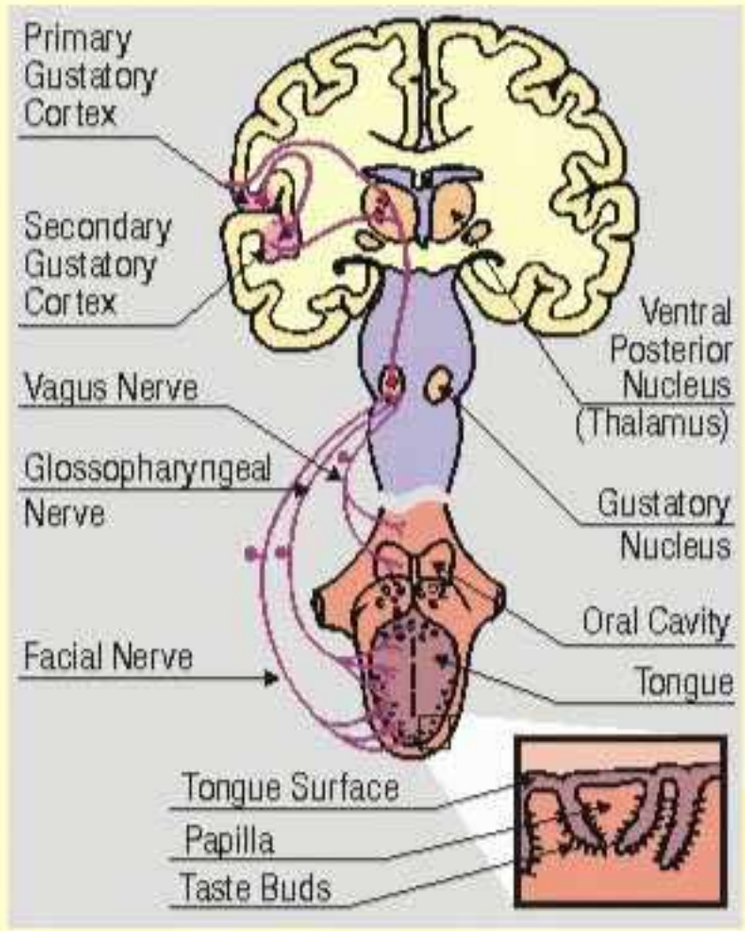
Taste	Substance	Threshold for tasting
Salt	NaCl	0.01 M
Sweet	Sucrose	0.01 M
Sour	HCl	0.0009 M
Bitter	Quinine	0.000008 M
Umami	Glutamate	0.0007 M

Taste

- The system is biased towards detecting poisons (bitter and sour)

- Receptors connect to the brain via cranial nerves

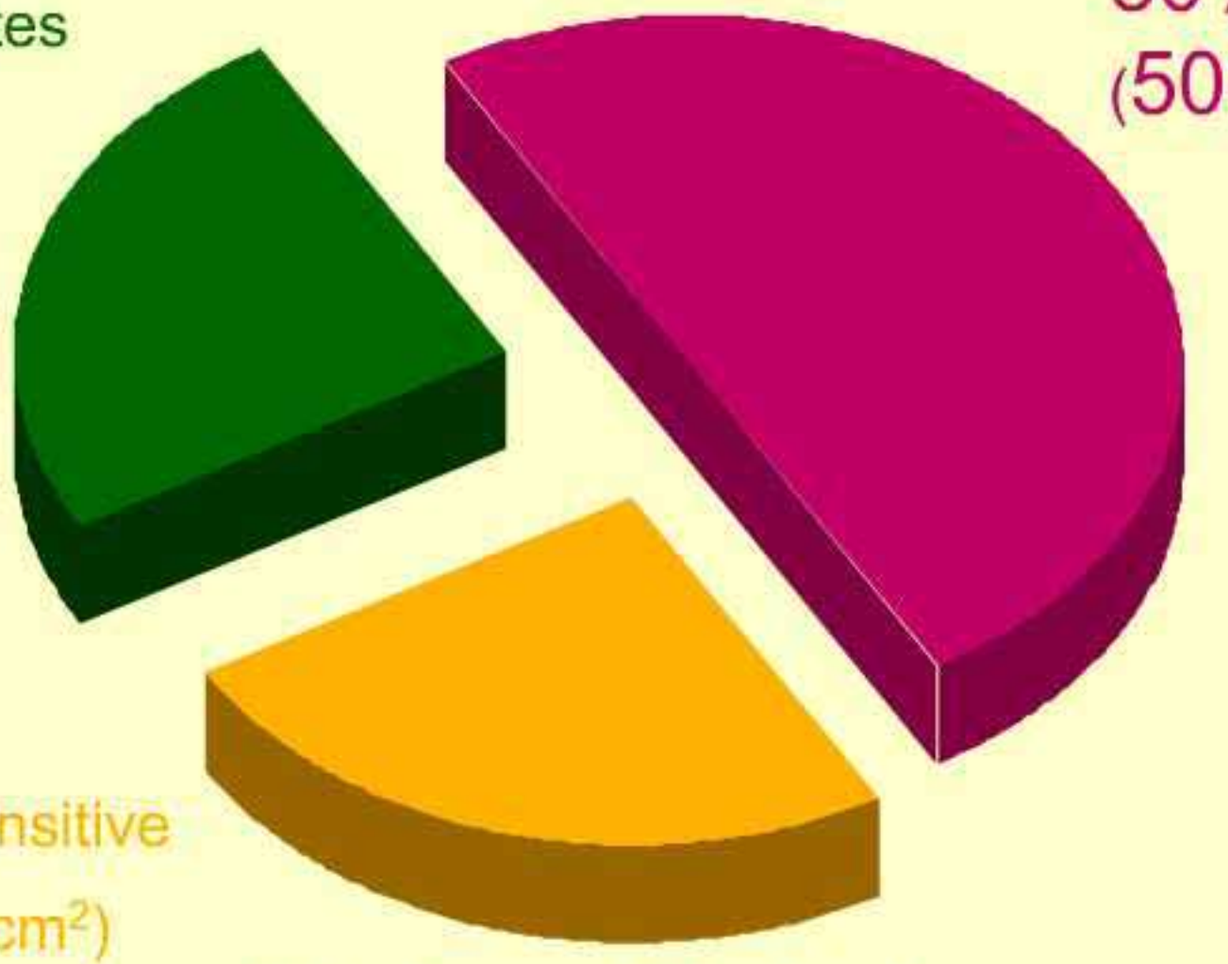
- Processing is in a brain region adjacent to the sense of touch region for the tongue



Taste

Large variation in taste sensitivity in human population

25% have super-sensitivity (1100 taste buds cm^2)
very sensitive to and put off by strong
bitter and sweet tastes
- rarely overweight



50% are average
(500 taste buds cm^2)

25% are very insensitive
(<100 taste buds cm^2)
insensitive to bitter and sweet tastes and like foods
high in these qualities - often overweight

Taste

- Females have greater sense of taste than males !

-

-

Taste

- Females have greater sense of taste than males !

- To protect babies against poisons during pregnancy ?

-

Taste

- Females have greater sense of taste than males !

- To protect babies against poisons during pregnancy ?

- Morning sickness reduces likelihood of miscarriages

Taste

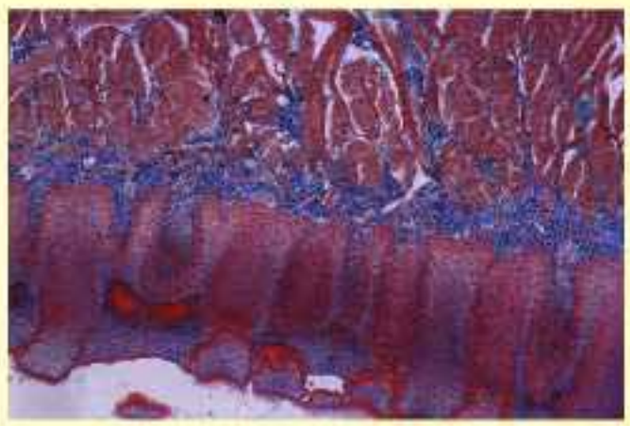
- Some other mammals are probably more sensitive to tastes than us:

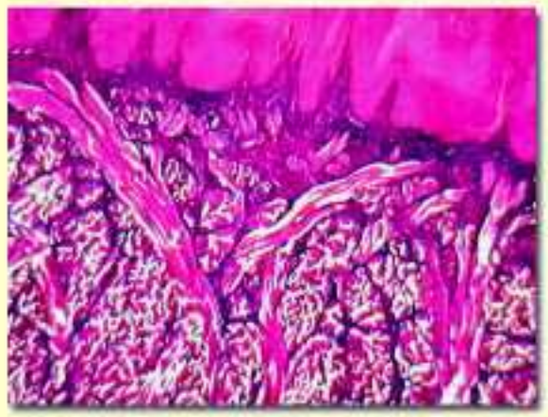
- Rabbit - 17,000 taste receptors

- Pigs - 15,000 taste receptors

- Humans - 9000 taste receptors

- This is probably the least well understood sense





Smell

- Most mammals depend on this sense much more than us

- Two different detection systems

- Liquid borne odours - pheromones
  (urine, saliva, glandular secretions)

- Air borne odours

- Both systems have large numbers of different receptors
  Pheromones - 100 ; Odours - 1000

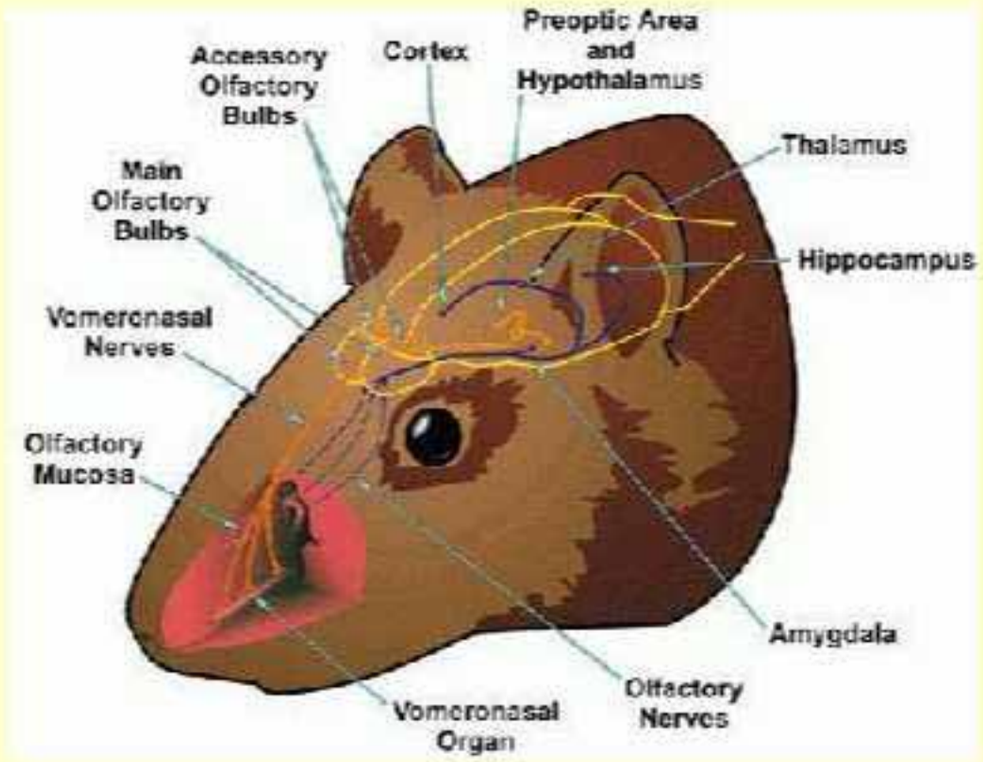
- Allow over 10,000 different smells to be detected !

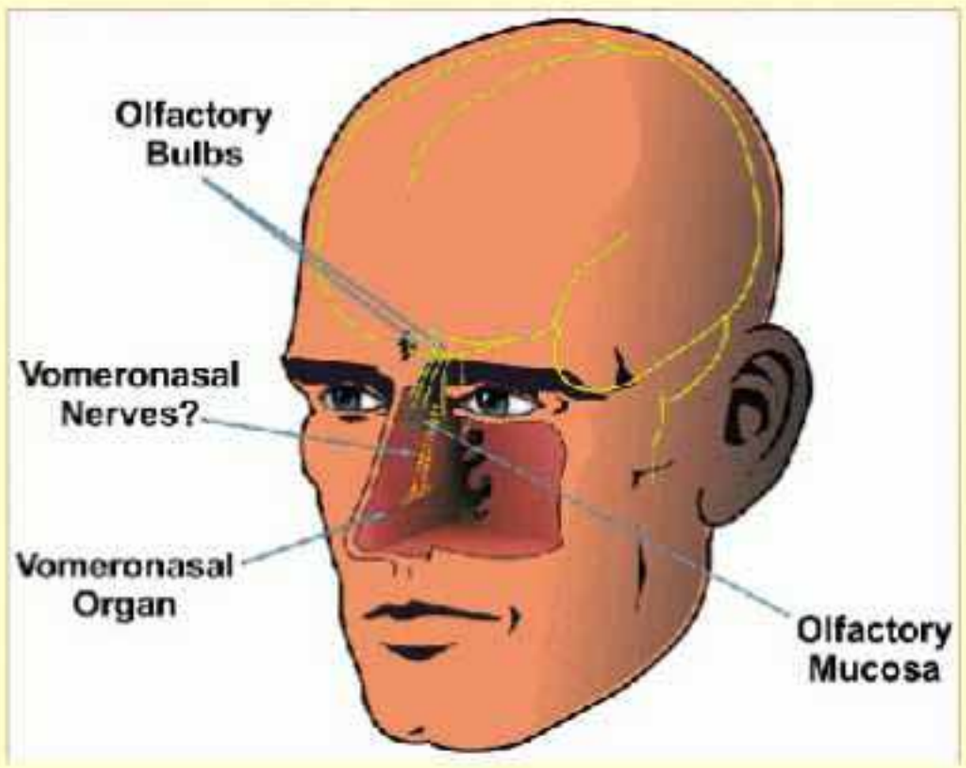
Smell
- detection of pheromones

- This is an involuntary, unconscious system

- Receptors in the vomeronasal organ

-





Smell
- detection of pheromones

- This is an involuntary, unconscious system

- Receptors in the vomeronasal organ

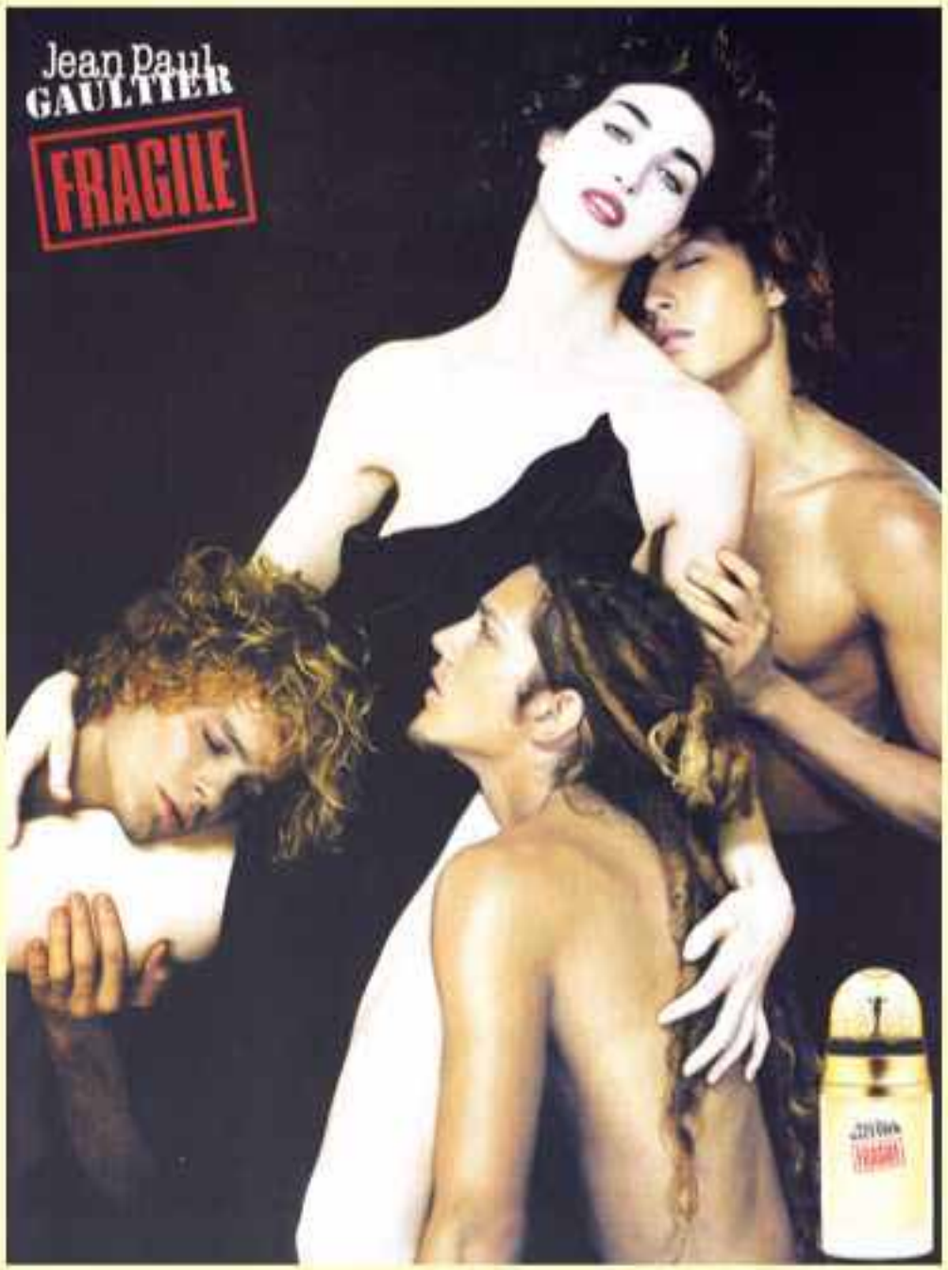
- Brain projections routed straight to regions controlling hormones, sex and emotion

- Male pigs and hamsters use it to promote sex response to female pheromones

- Female mice use it to remember the male that had sex with them

- In humans often referred to as the 6^{th} sense

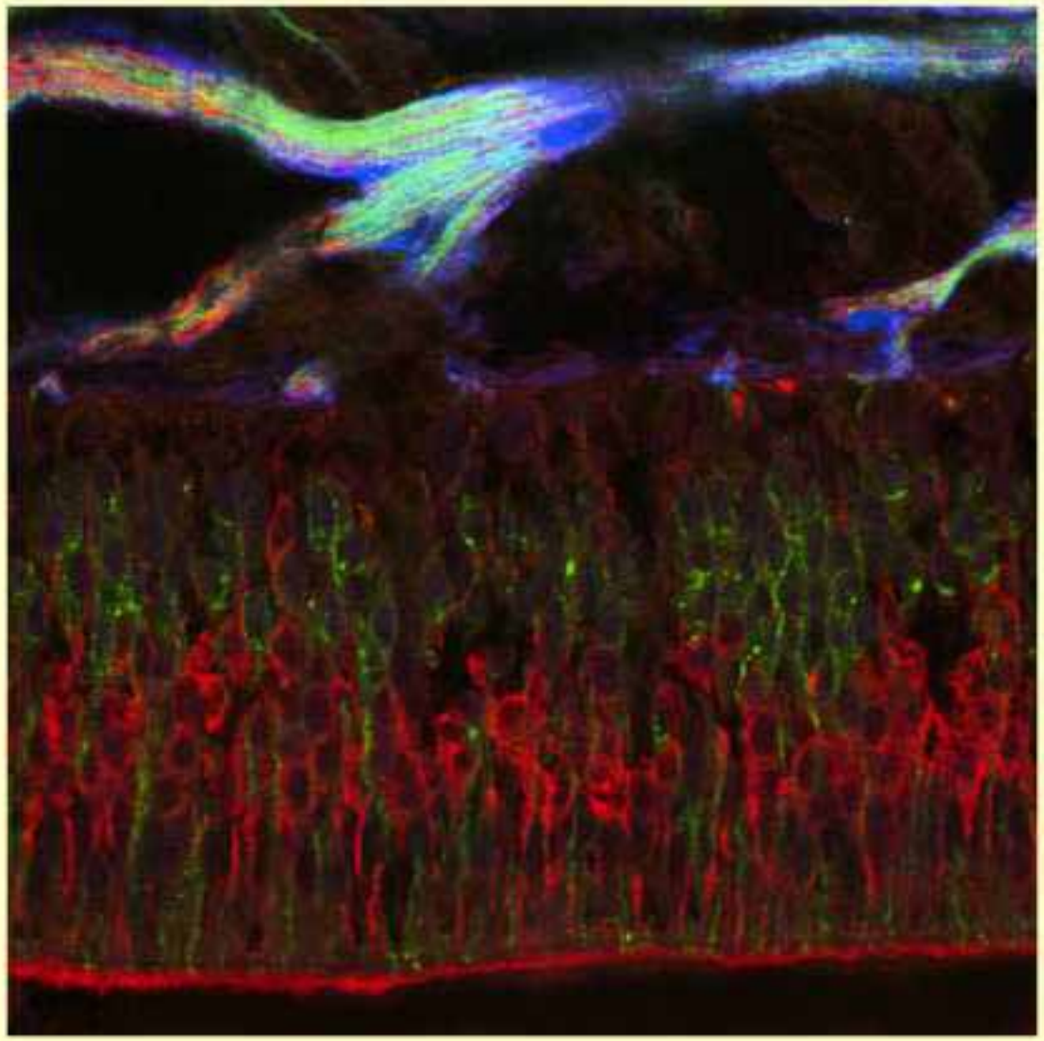
Smell



Smell
- detection of air-borne odours

- 1000 receptor types localised in olfactory epithelium

-



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Smell
- detection of air-borne odours

- 1000 receptor types localised in olfactory epithelium

- Other species have much larger olfactory epitheliums:

Dog - 150 cm^2

German Shepherd
220 million

Cat - 14 cm^2

Cat
60 million

Human - 4 cm^2

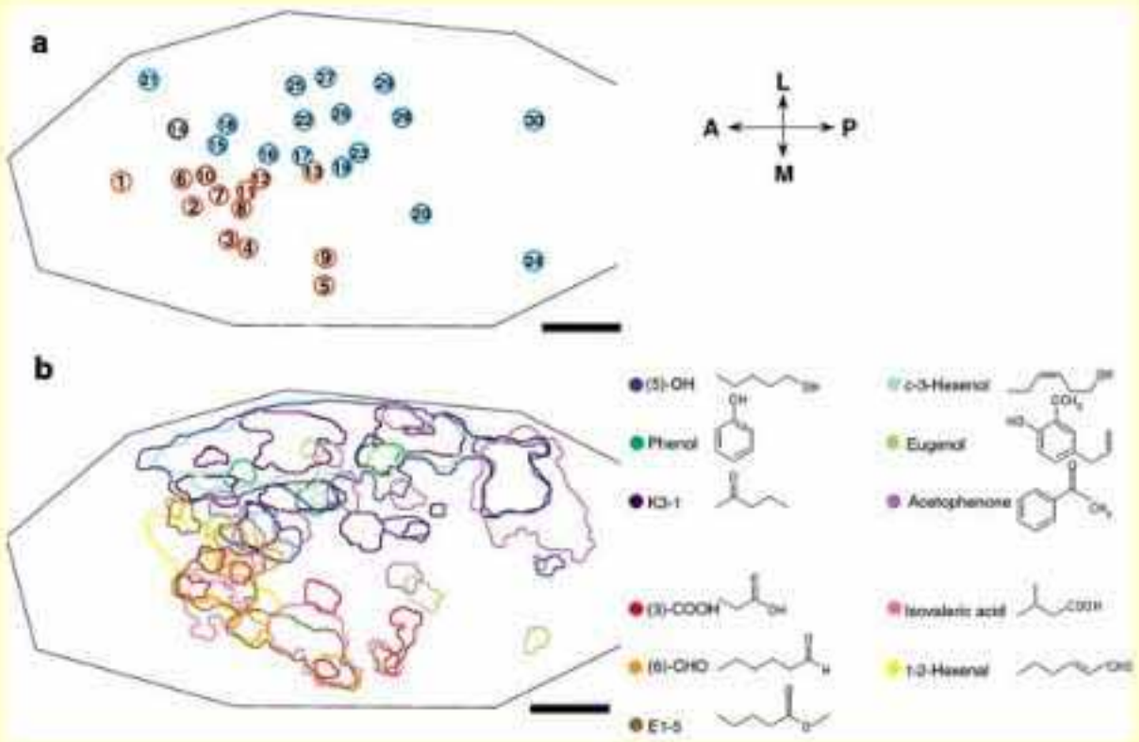
Human
6 million

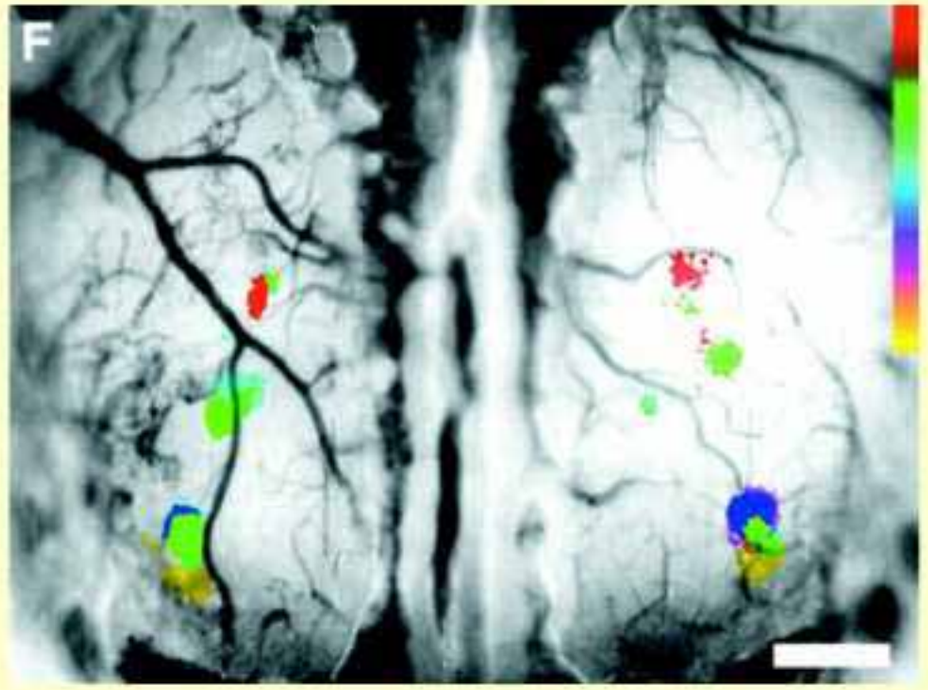
- Receptor numbers

Smell
- Brain processing of smell

- Odours are spatially mapped in olfactory bulb

-



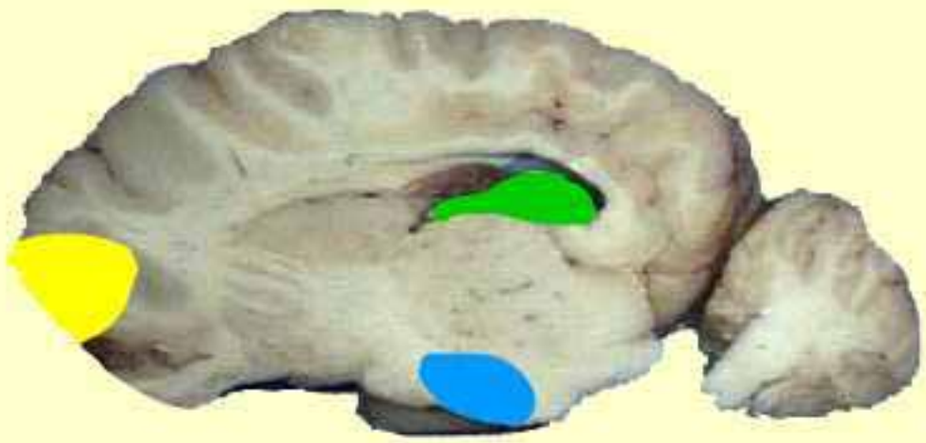


Smell
- Brain processing of smell

- Odours are spatially mapped in olfactory bulb

- Projections are then sent directly to areas dealing with:

- memory (hippocampus)
- emotion (amygdala)
- control of attention and action (frontal cortex)



Smell
- Aromatherapy

Smells are highly memorable and evoke strong attentional and emotional reactions:

Peppermint: refreshing and stimulating, increases alertness, relieves pain, indigestion, nausea and headaches

Rosemary: a stimulant that promotes mental clarity and alertness

Sandalwood: warm, sensual aroma, euphoric and seductive

Ylang-ylang: alleviates anger, anxiety and stress

(Hammers, 1995)

Smell

- This sense can be used to detect and localise odours over very long-distances

- Comes into its own for close-up following of odour trails

- What must the experience be like for a dog ?

-

Smell

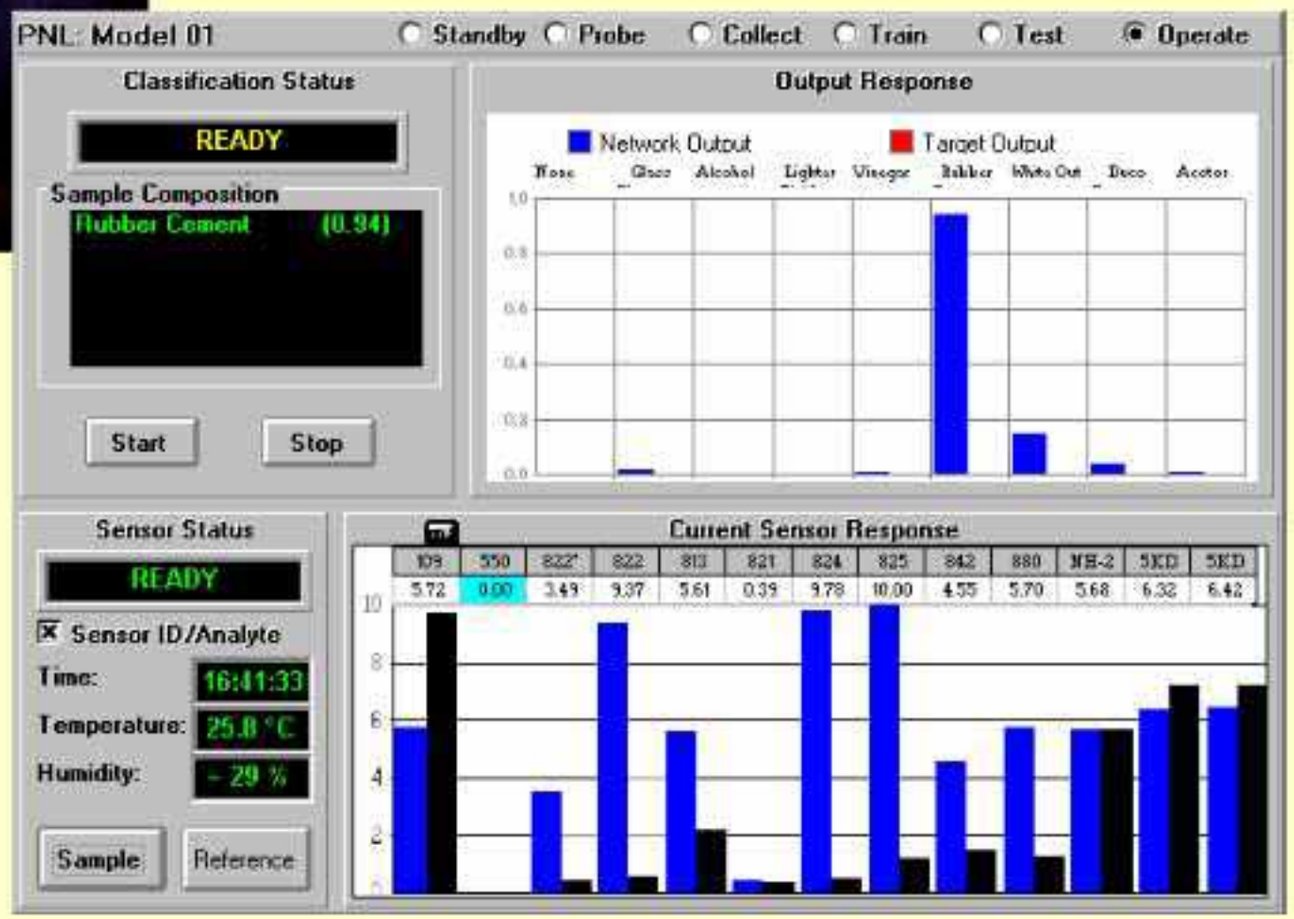
- This sense can be used to detect and localise odours over very long-distances

- Comes into its own for close-up following of odour trails

- What must the experience be like for a dog ?

- Detecting emotional and hormonal changes and disease

Smell
- Electronic noses



Hearing

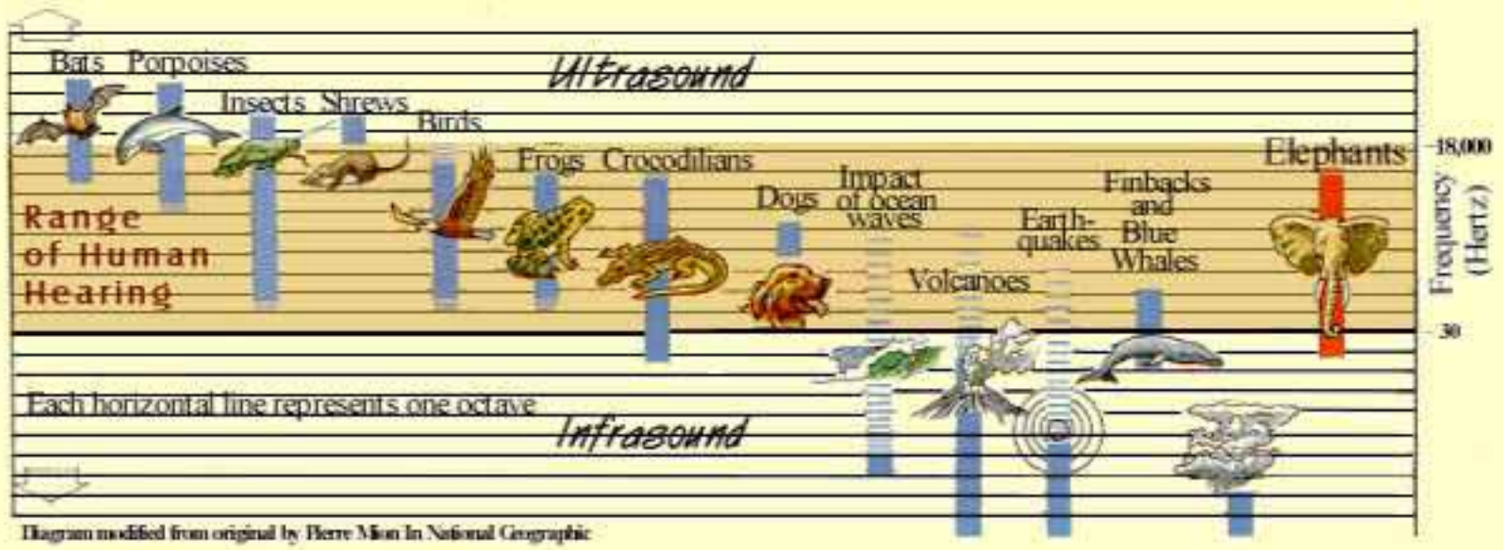
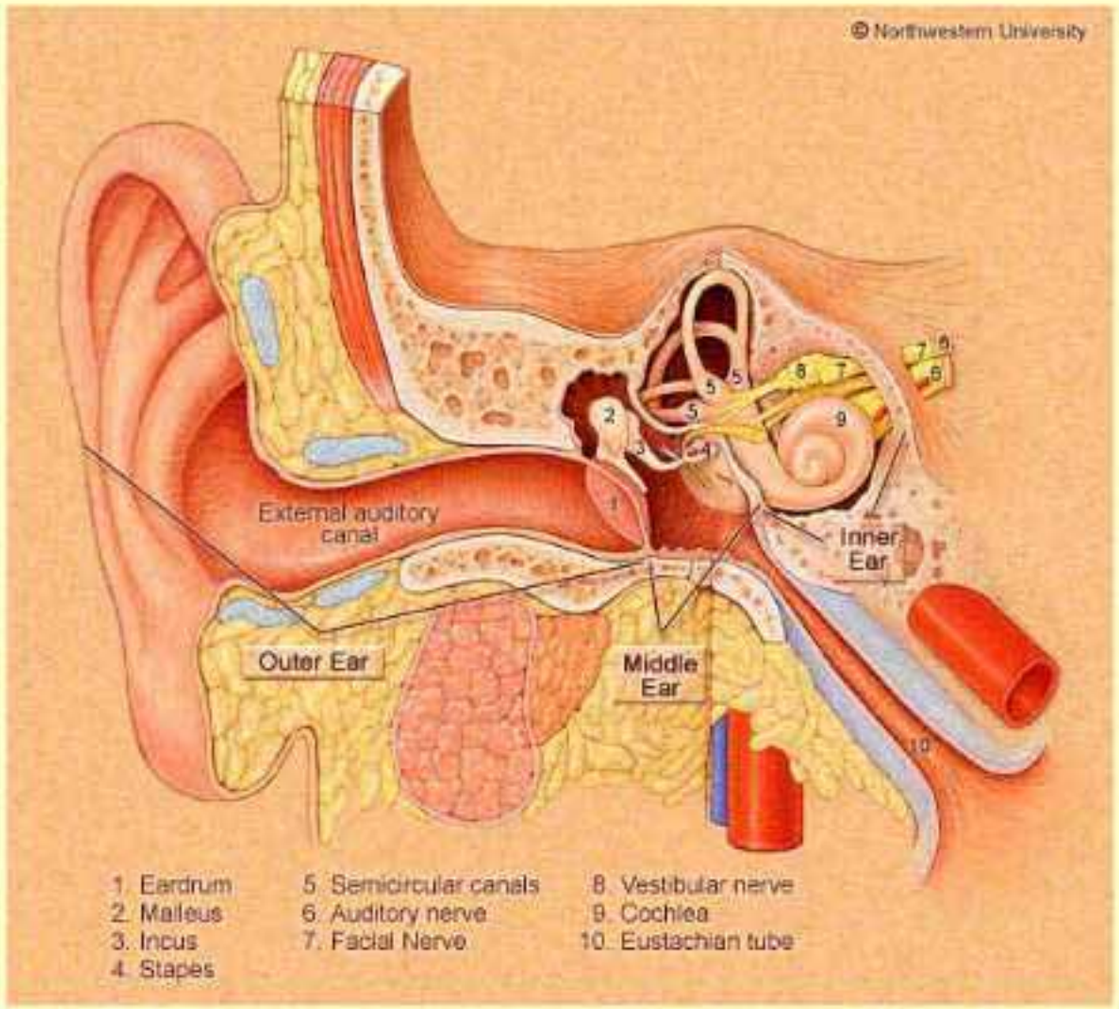


Diagram modified from original by Pierre Mion In National Geographic

Hearing



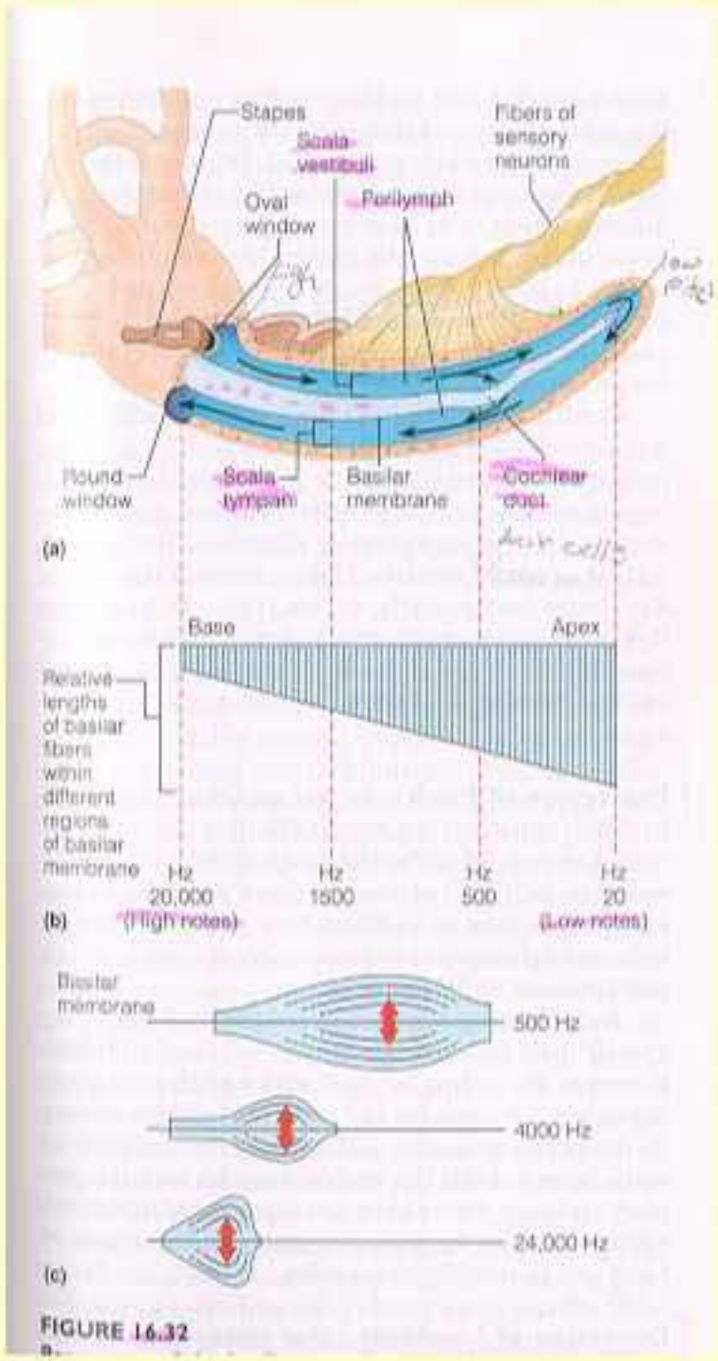


FIGURE 16.32

Hearing

- We hear our own voices through our heads !

- Dolphins hear through their lower jaw

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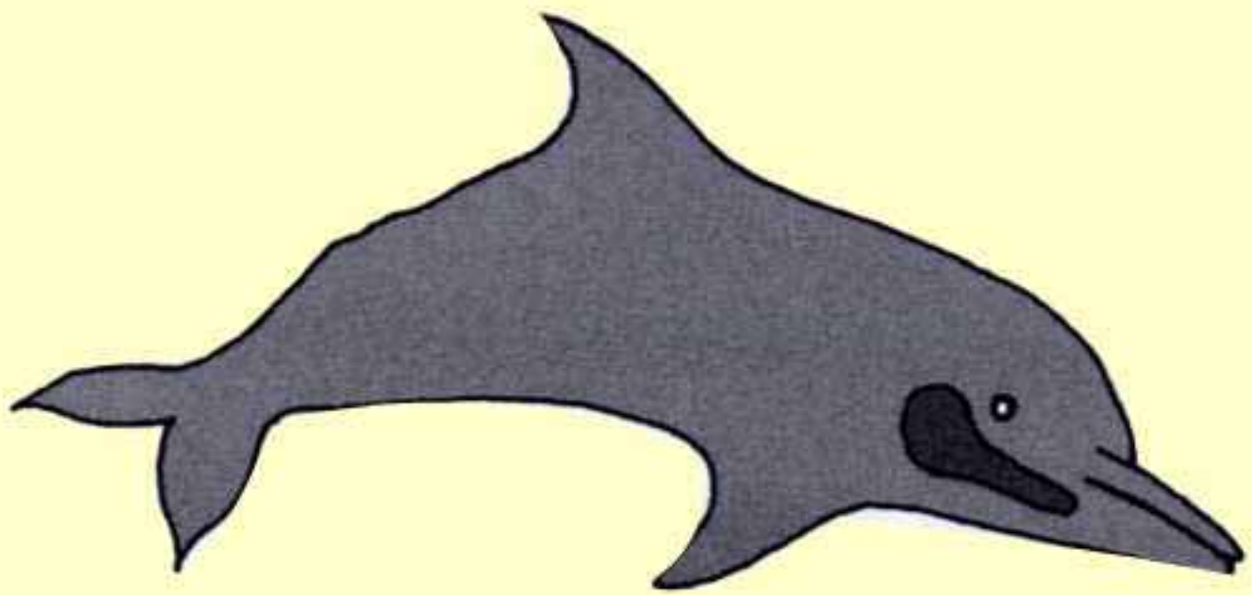


Hearing

- We hear our own voices through our heads !

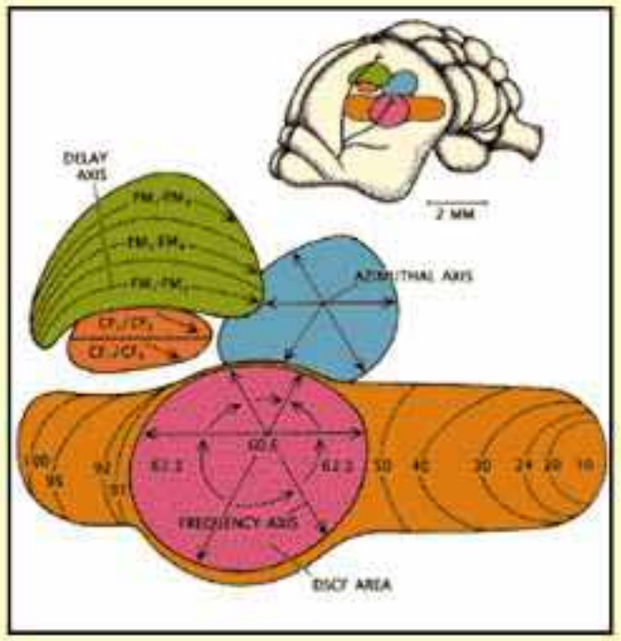
- Dolphins hear through their lower jaw

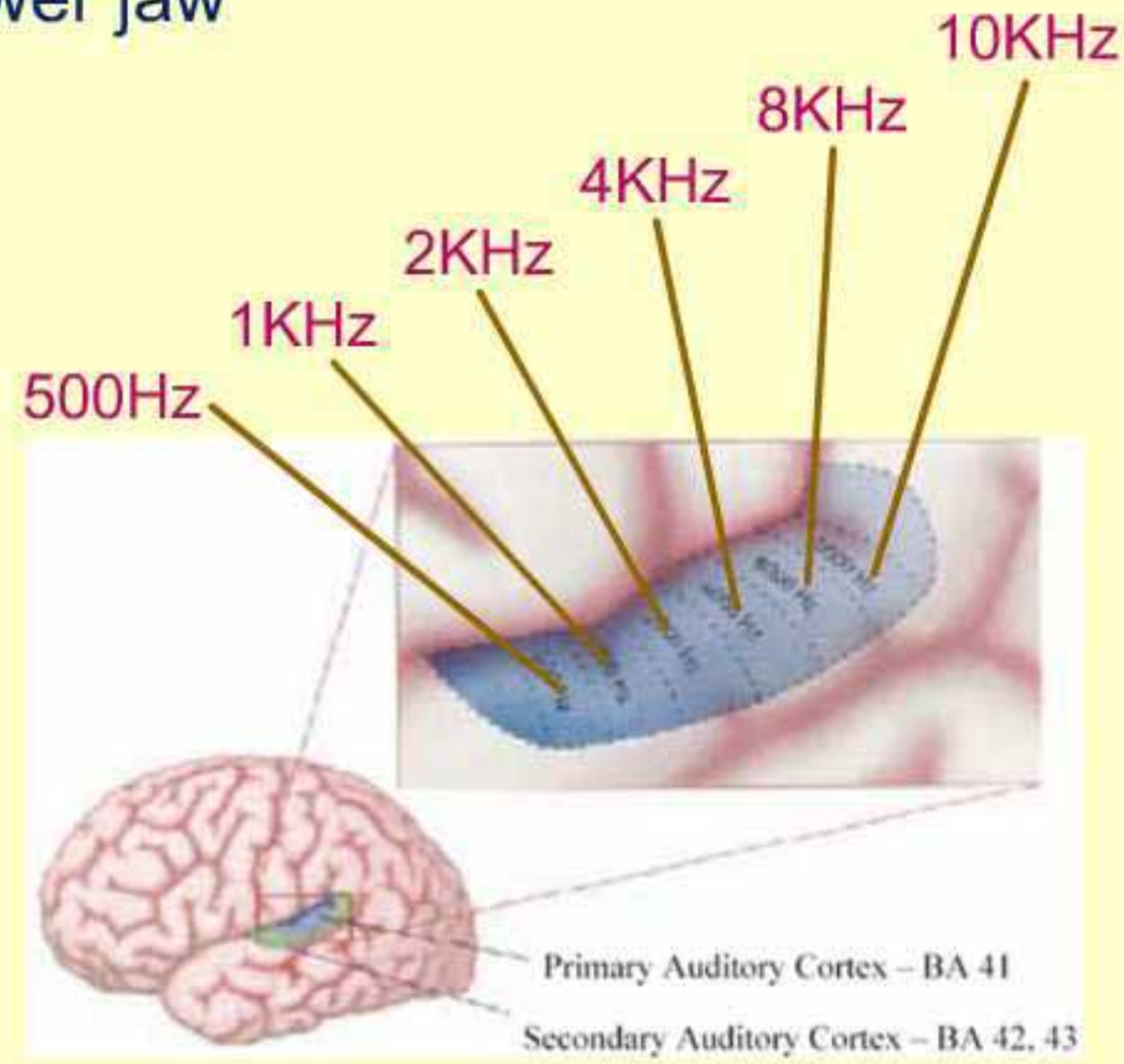
- Auditory maps in the brain

-

-

-





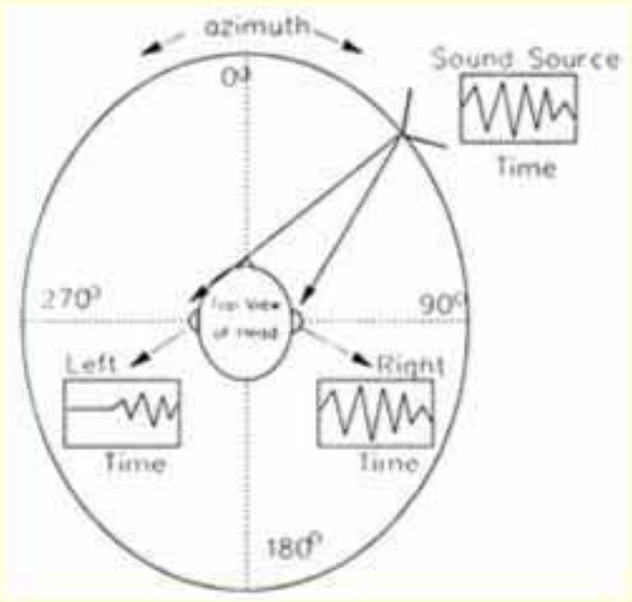
Hearing

- We hear our own voices through our heads !

- Dolphins hear through their lower jaw

- Auditory maps in the brain

- Computing sound direction



-

-

Mouse
12 - 20 KHz

Wavelength of sound must be at least twice the width of the head

Human
2 KHz

Hearing

- We hear our own voices through our heads !

- Dolphins hear through their lower jaw

- Auditory maps in the brain

- Computing sound direction

- Human hearing range 20 - 40Hz up to 15 - 20KHz

-

Hearing

- We hear our own voices through our heads !

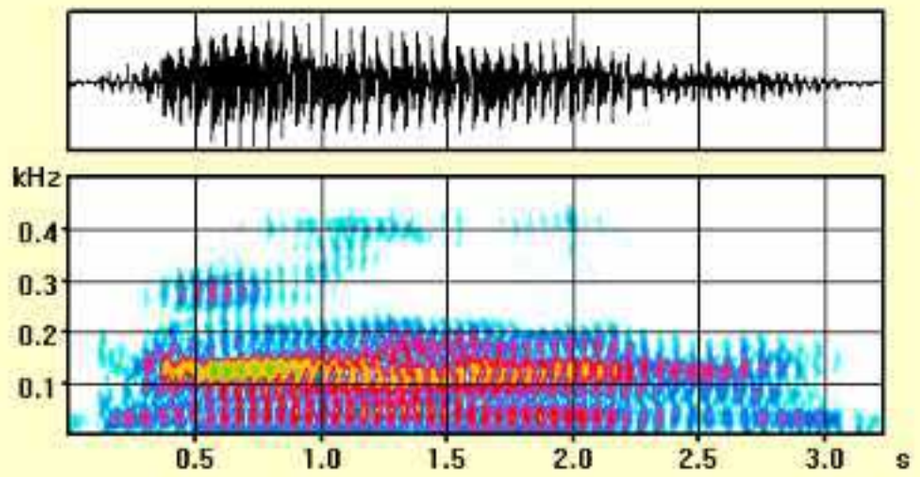
- Dolphins hear through their lower jaw

- Auditory maps in the brain

- Computing sound direction

- Human hearing range 20 - 40Hz up to 15 - 20KHz

- Detecting infrasound
  1 - 20Hz



Hearing

- Long-distance detection of earth tremors, storms etc

- Detecting ultrasound (40 - 120KHz)

    - bats - 120Khz
    - mice - 100KHz
    - dolphins - 100KHz
    - cats - 64KHz
    - dogs - 45KHz

-

-

-

Hearing

- Long-distance detection of earth tremors, storms etc

- Detecting ultrasound (40 - 120KHz)

  - bats - 120Khz
  - mice - 100KHz
  - dolphins - 100KHz
  - cats - 64KHz
  - dogs - 45KHz

- Used by small rodents to signal distress or pain

-

-

Hearing

- Long-distance detection of earth tremors, storms etc

- Detecting ultrasound (40 - 120KHz)

  - bats - 120Khz
  - mice - 100KHz
  - dolphins - 100KHz
  - cats - 64KHz
  - dogs - 45KHz

- Used by small rodents to signal distress or pain

- and..... by males after sex !

- Predators have adapted to hear these calls

Hearing
- Biosonar

Detection to catch time
is around **0.5** seconds

Bats catch
300 - 600
insects per hour

Done at **20 - 30** mph
with many hundreds
of other bats around

- Biosonar

Detection to catch time
is around **0.5** seconds

Bats catch
300 - 600
insects per hour

Done at **20 - 30** mph
with many hundreds
of other bats around

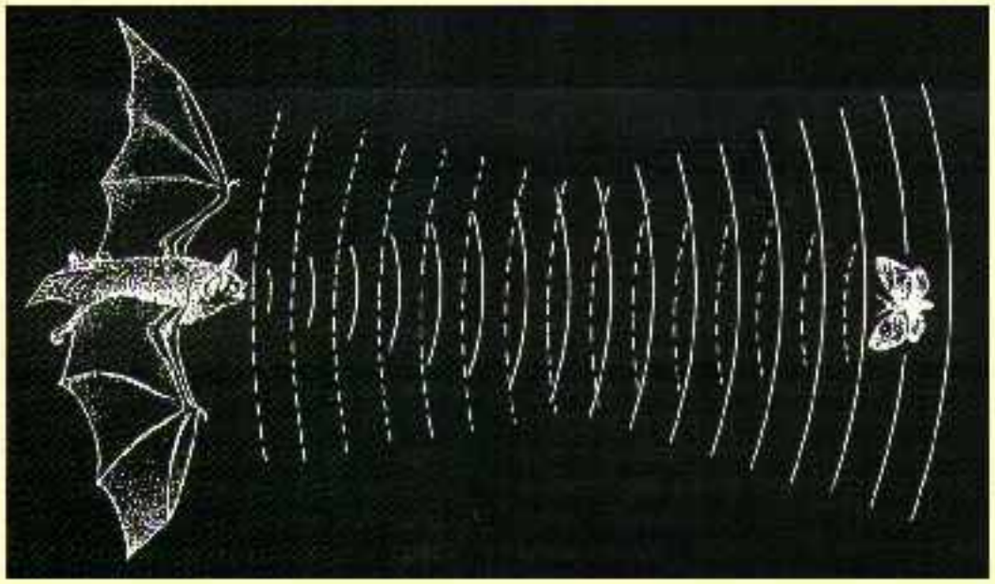
All in complete darkness !

Hearing
- Biosonar

How do they do it ?

-

-



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Hearing
- Biosonar

How do they do it ?

- They use specific frequency calls and detect echoes from each component

-

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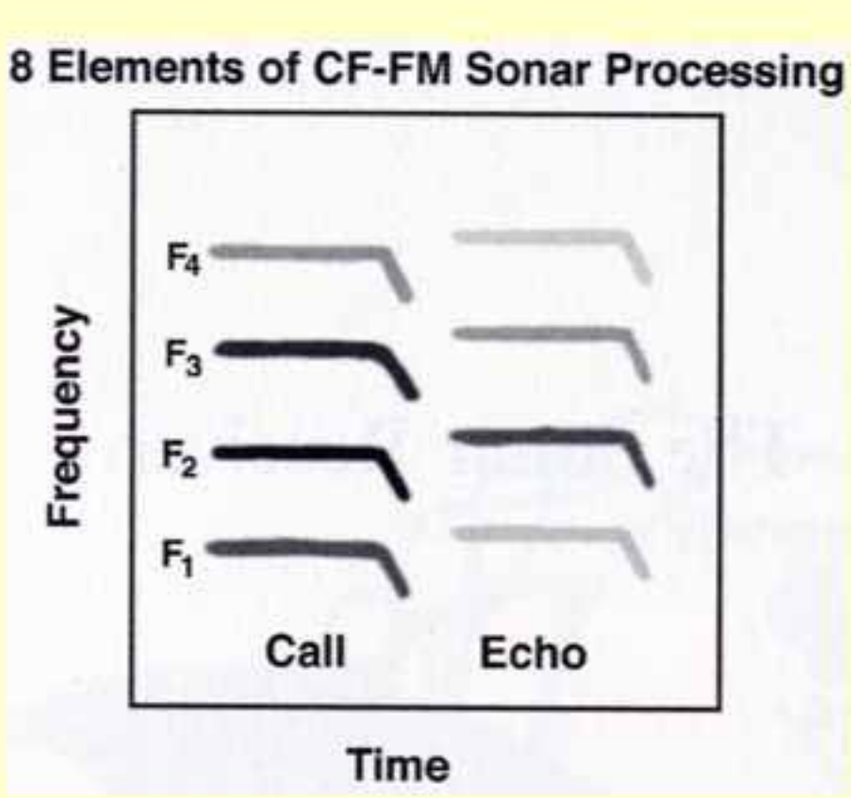

Hearing
- Biosonar

How do they do it ?

- They use specific frequency calls and detect echoes from each component

- Type of fly identified by wing-beat altering pattern of echo

-

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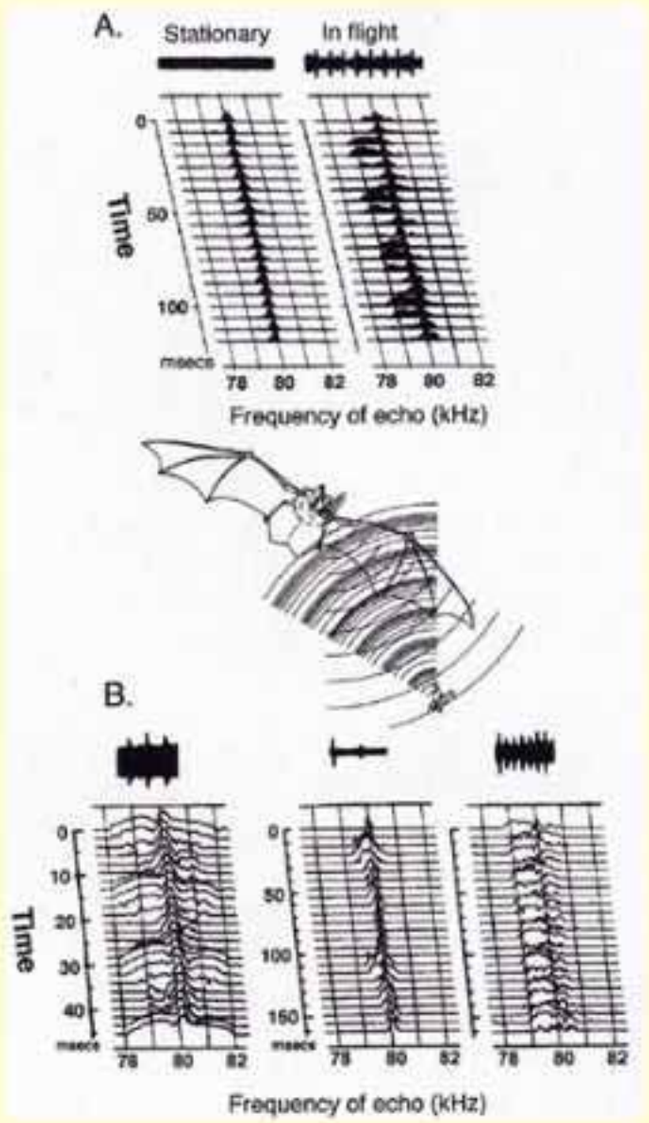


Hearing
- Biosonar

How do they do it ?

- They use specific frequency calls and detect echoes from each component

- Type of fly identified by wing-beat altering pattern of echo

- The calls are extremely loud !

-

-

Hearing
- Biosonar

How do they do it ?

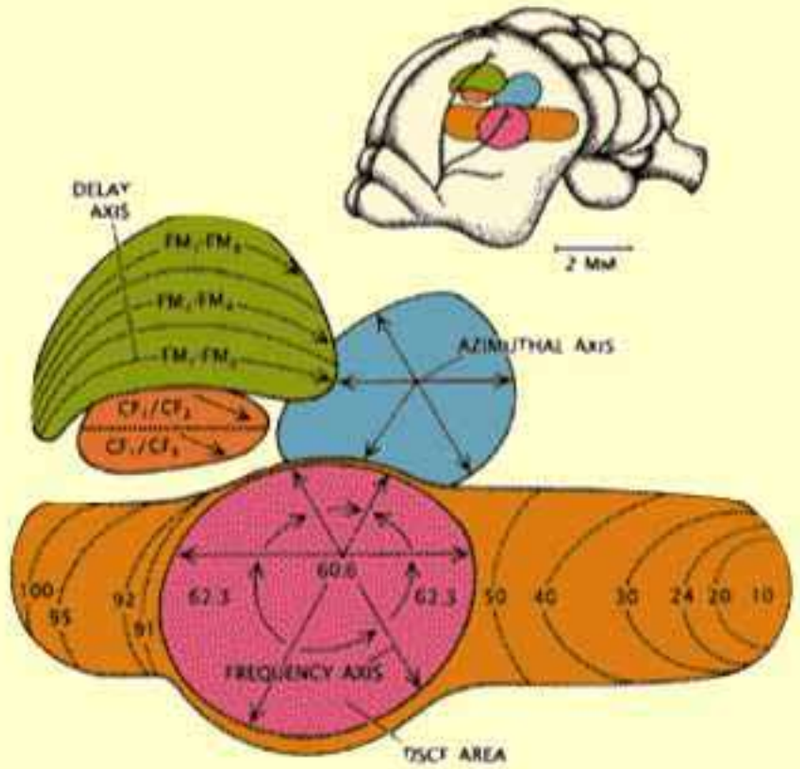
- They use specific frequency calls and detect echoes from each component

- Type of fly identified by wing-beat altering pattern of echo

- The calls are extremely loud !

- The brain map of auditory space is biased to 30, 60 and 90Khz

-



Hearing
- Biosonar

How do they do it ?

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- Type of fly identified by wing-beat altering pattern of echo

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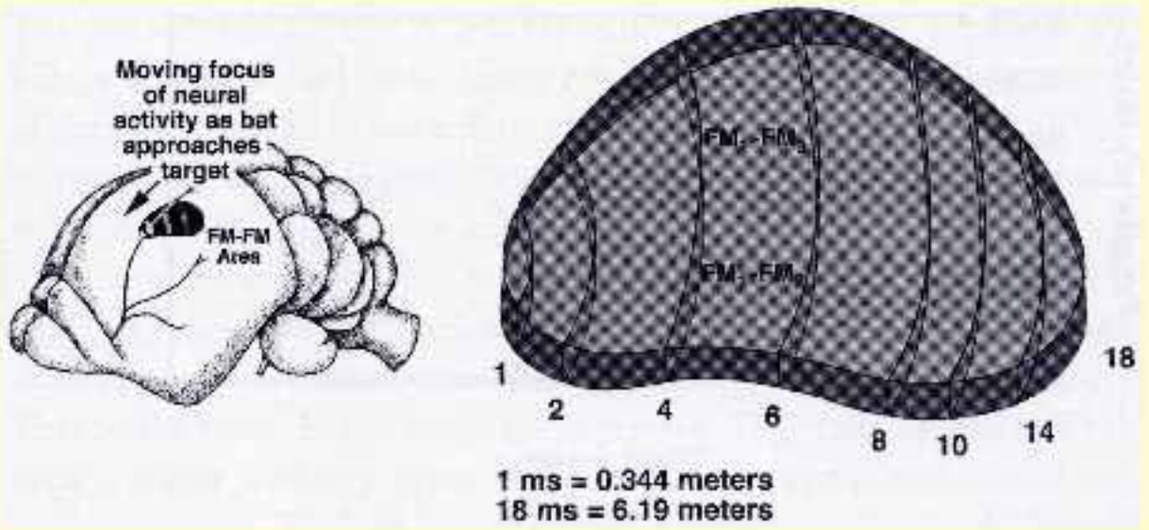


- Secondary maps compute temporal sequence of call and echo

Hearing
- Biosonar

Sequence of events

- Searching sweep just with constant frequency

- Echo detected from fly

- Increase call frequency and add FM sweep

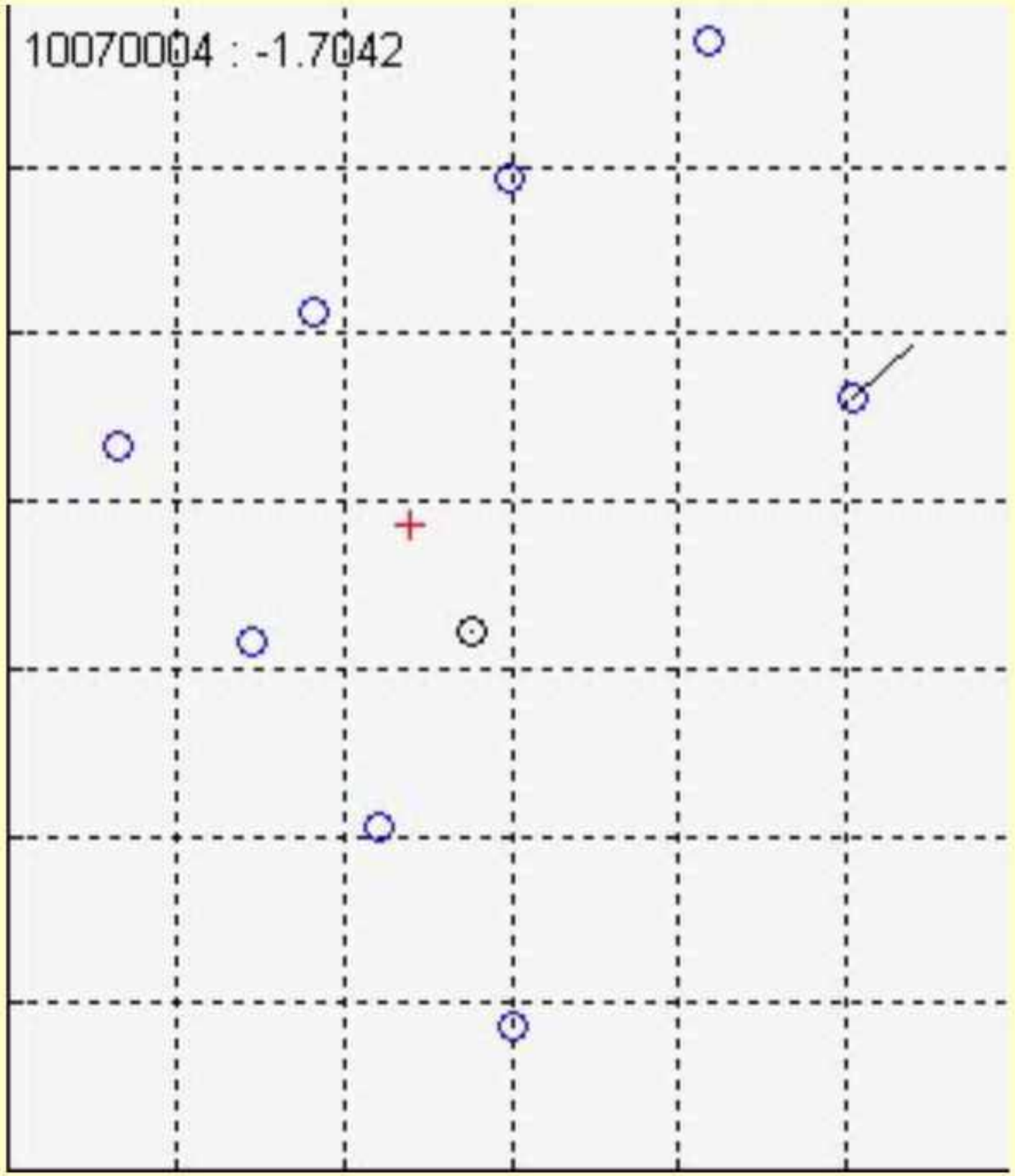
- Compute direction

- Identify type of fly

- Compute speed and distance

- Alter call frequency

Hearing
- Biosonar



Hearing
- Biosonar

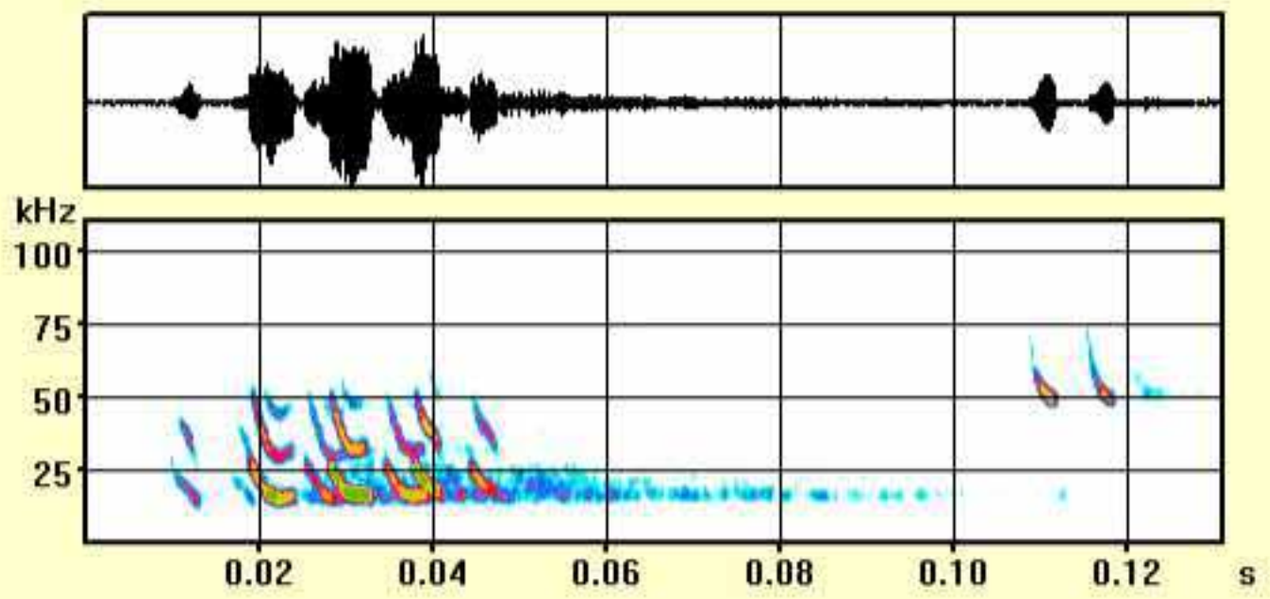
Why are they not confused by calls and echoes from other bats ?

- Two key factors:

- They know which is their own voice (30KHz component)

-

-



Hearing
- Biosonar

Why are they not confused by calls and echoes from other bats ?

- Two key factors:

- They know which is their own voice (30KHz component)

- All of their brain cells that need inputs from two frequencies in sequence must receive the 30KHz sound first

-

Hearing
- Biosonar

Why are they not confused by calls and echoes from other bats ?

- Two key factors:

- They know which is their own voice (30KHz component)

- All of their brain cells that need inputs from two frequencies in sequence must receive the 30KHz sound first

- They know when they should receive back the corresponding 60KHz echo

Hearing
- Biosonar

- Dolphins are similar but:

- Use broadband calls produced through the nose

-

-

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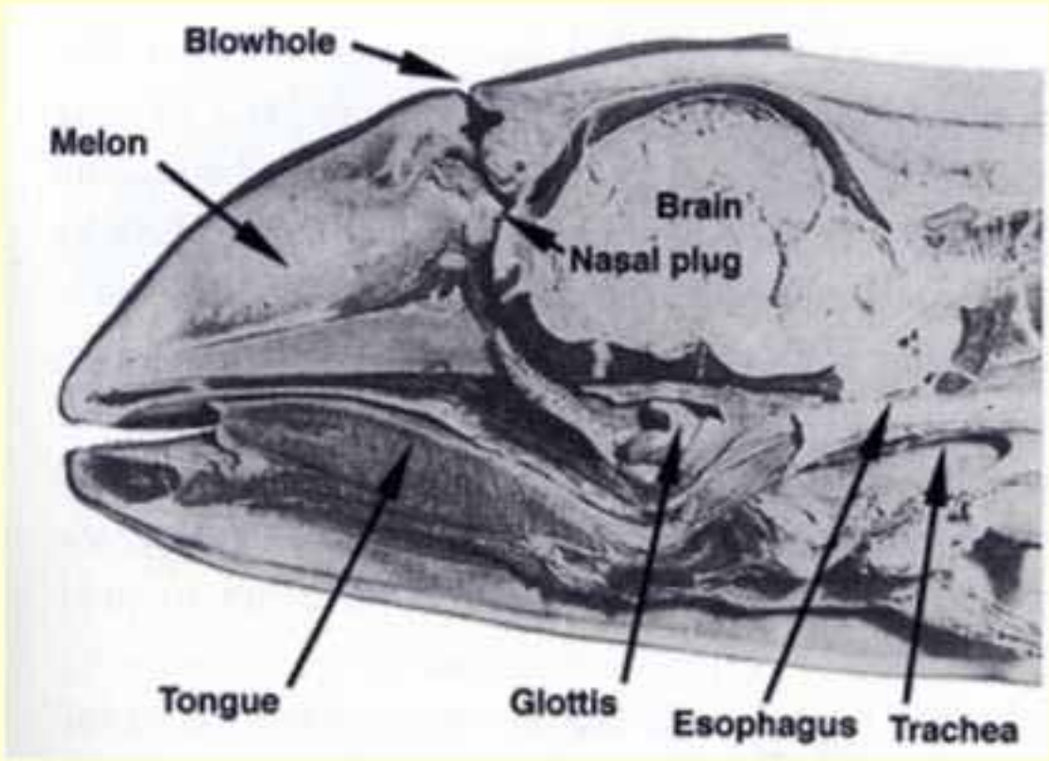

Hearing
- Biosonar

- Dolphins are similar but:

- Use broadband calls produced through the nose

- Hear echoes through the lower jaw

-

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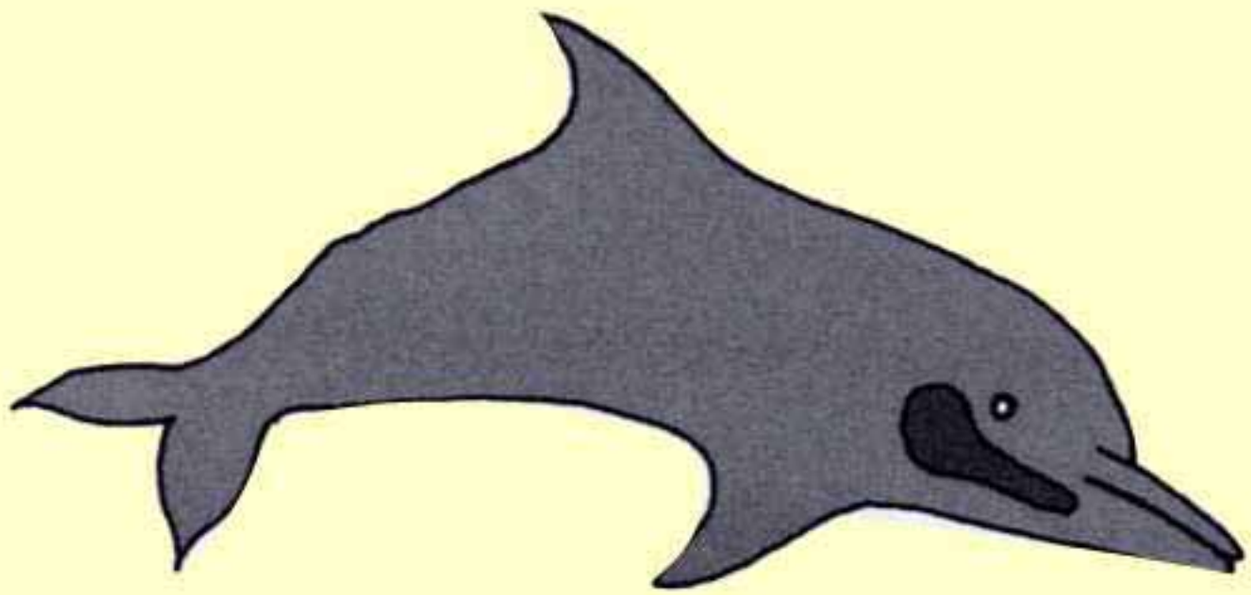


Hearing
- Biosonar

- Dolphins are similar but:

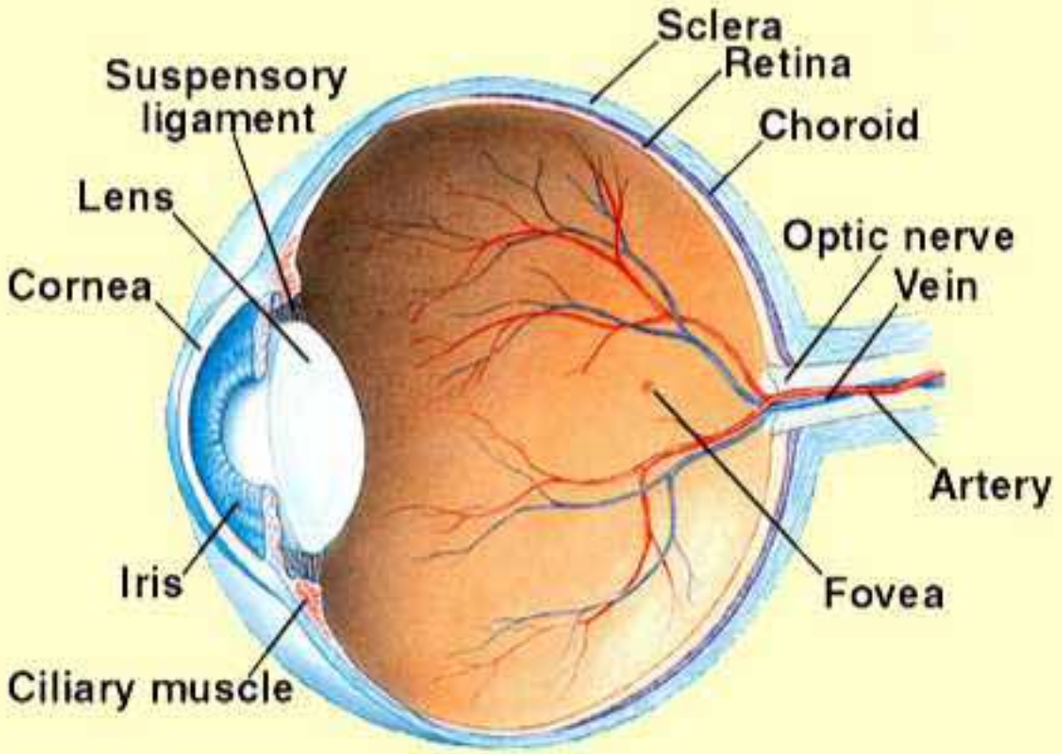
- Use broadband calls produced through the nose

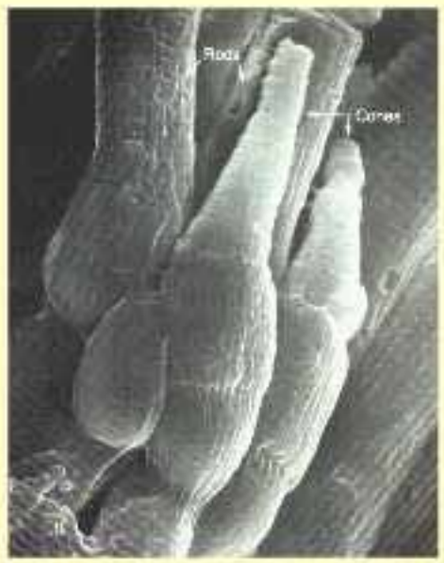
- Hear echoes through the lower jaw

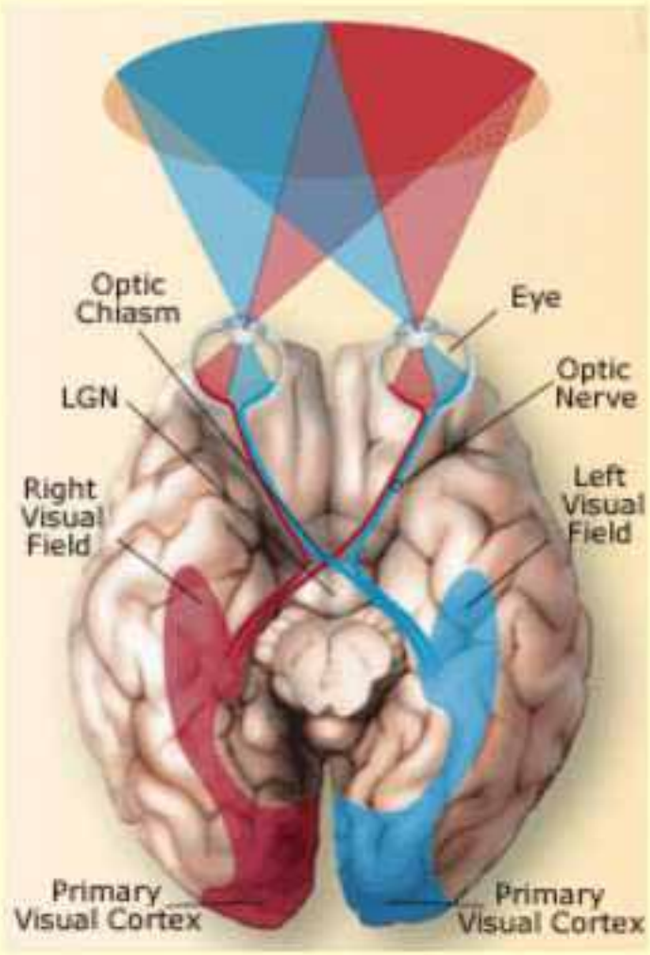
- Can detect objects up to 100 metres or more

- Have amazing impedance matching strategies using fat

Vision and magnetoreception
- The visual system



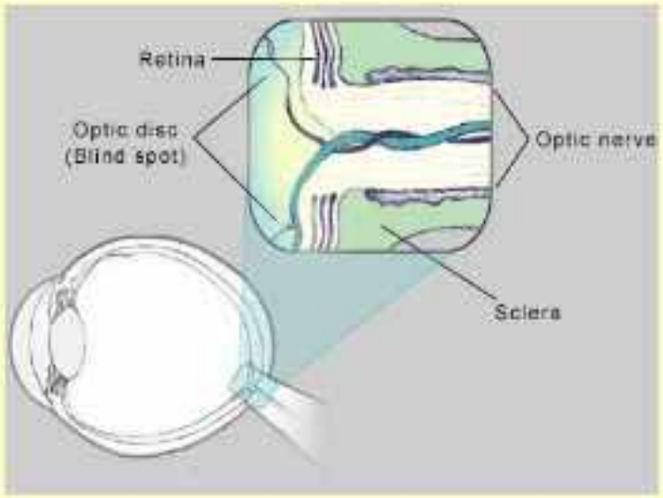


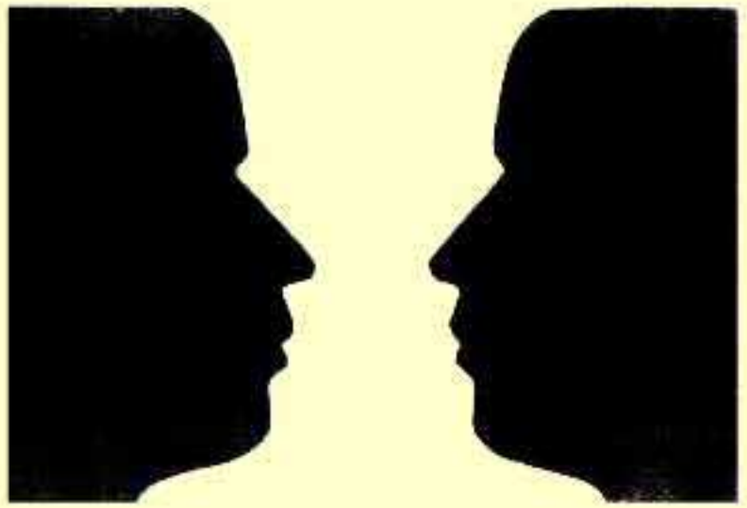


Vision and magnetoreception

- The brain makes lots of computational assumptions

-





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Vision and magnetoreception

- The brain makes lots of computational assumptions

- Retinotopic maps and multiple visual areas linked in parallel

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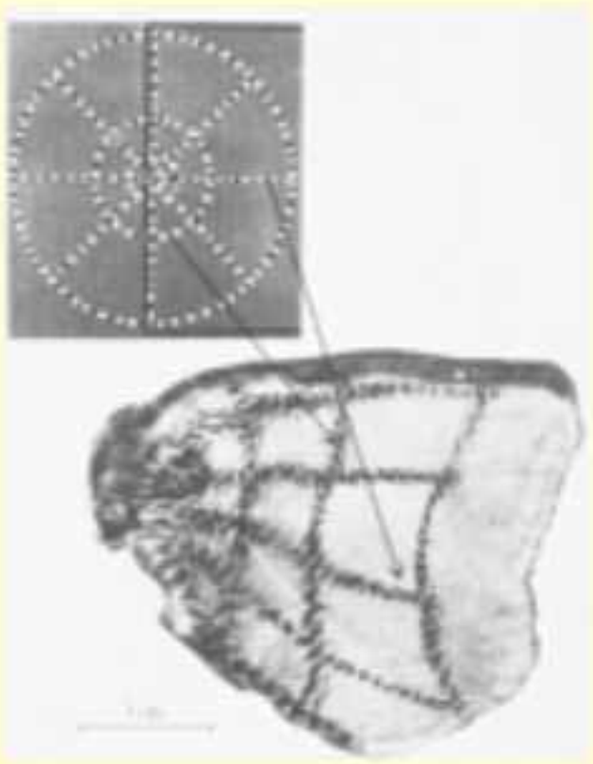

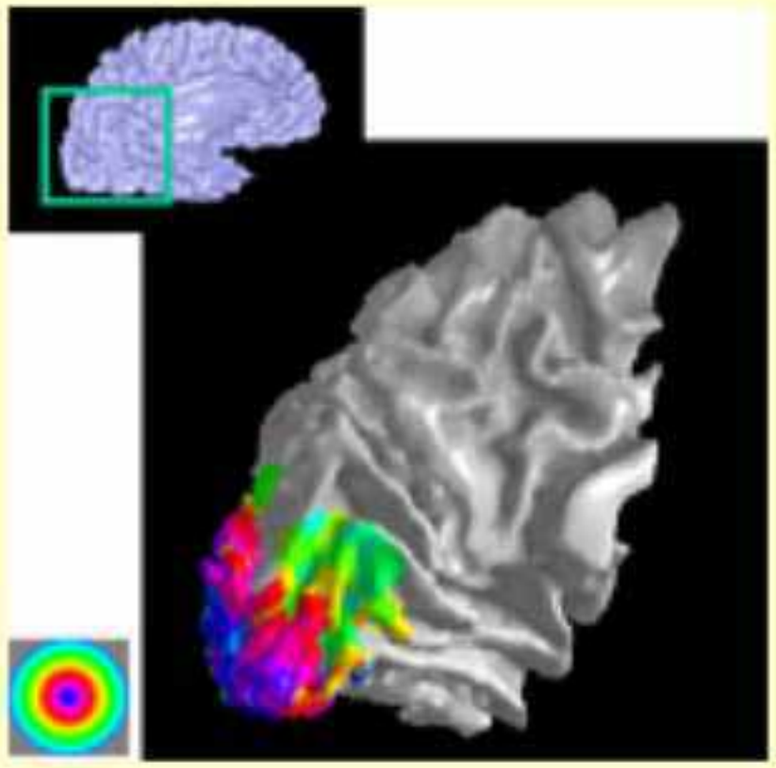

Vision and magnetoreception

- The brain makes lots of computational assumptions

- Retinotopic maps and multiple visual areas linked in parallel

- What and where are dealt with separately

-

-

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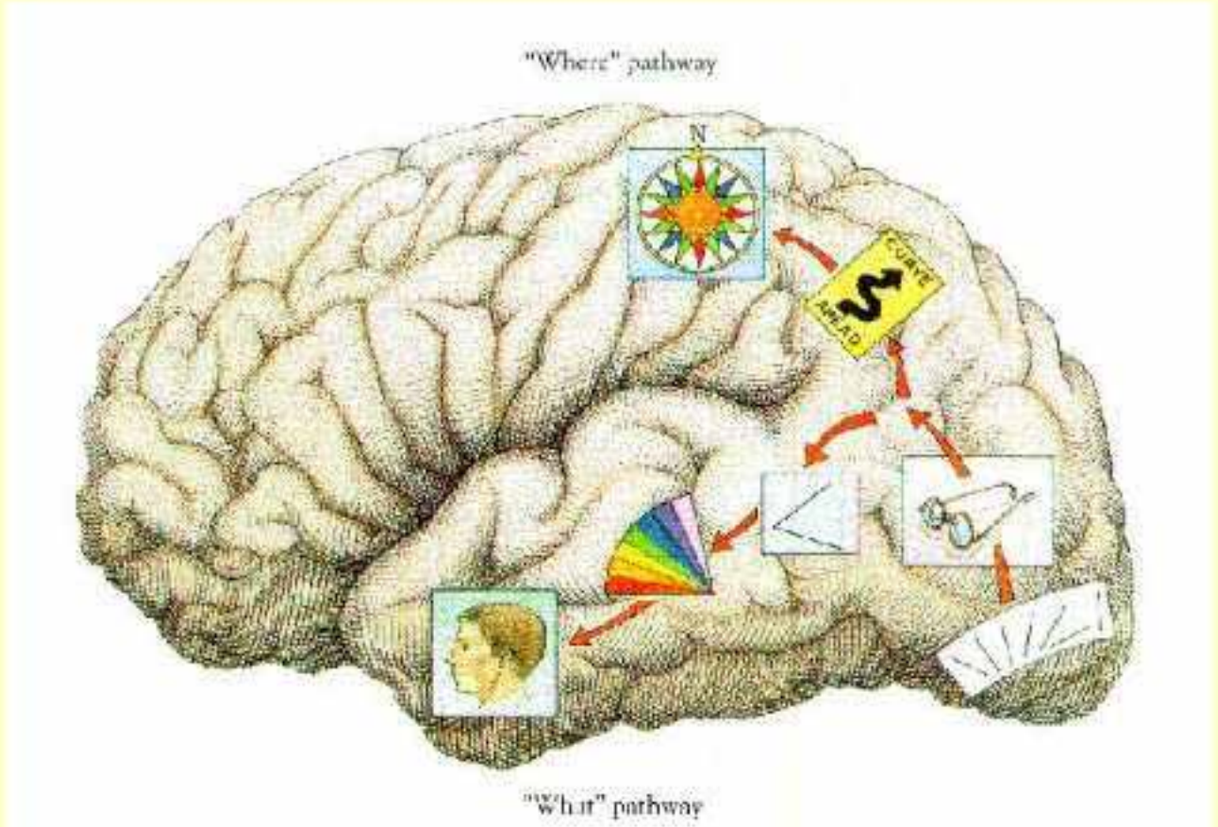

Vision and magnetoreception

- The brain makes lots of computational assumptions

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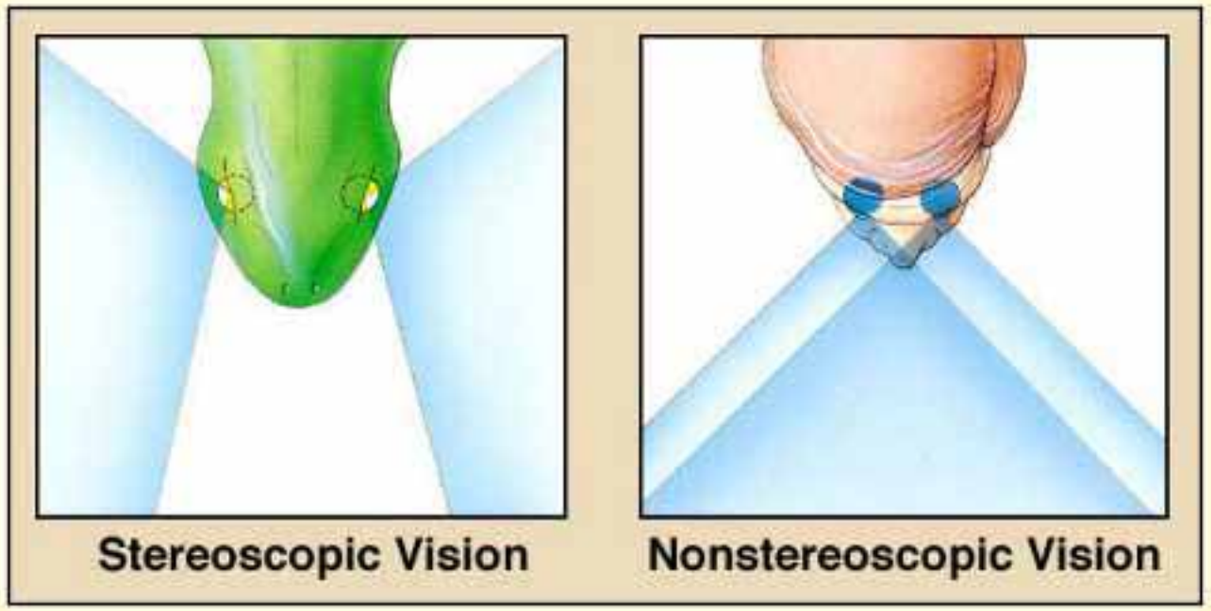
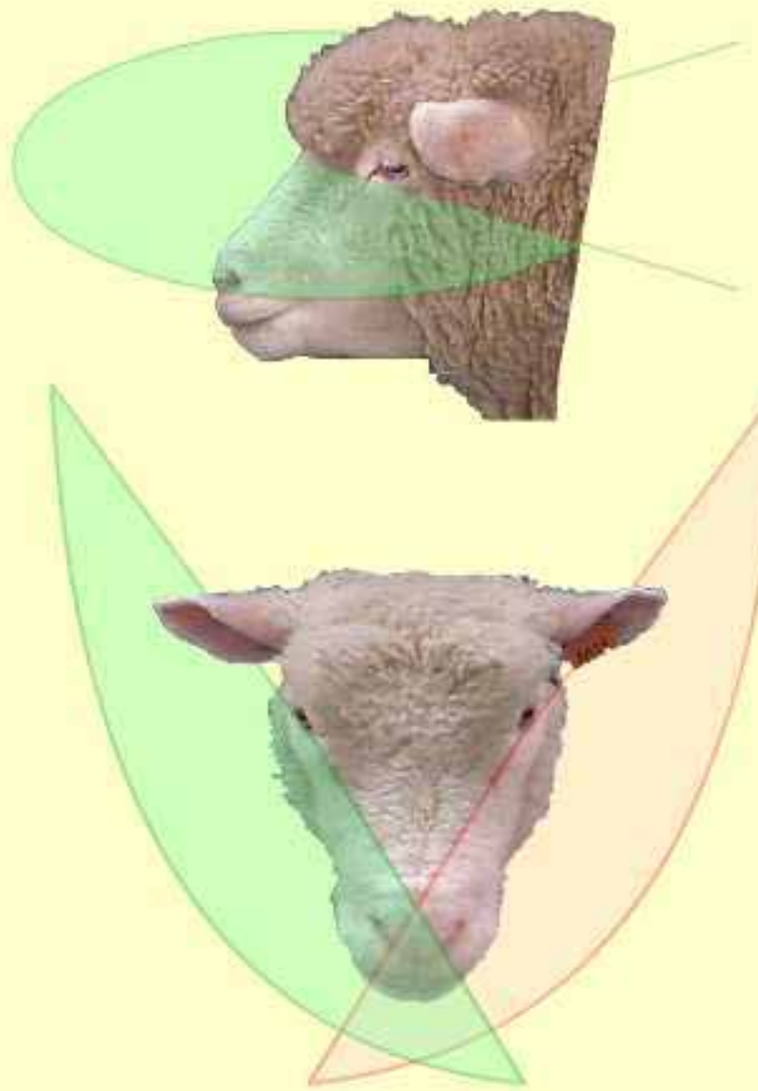
- What and where are dealt with separately

- Visual fields and binocular overlap

-

-





Vision and magnetoreception

- The brain makes lots of computational assumptions

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- What and where are dealt with separately

- Visual fields and binocular overlap

- Most mammals are good in the dark

-

Vision and magnetoreception

- The brain makes lots of computational assumptions

- Retinotopic maps and multiple visual areas linked in parallel

- What and where are dealt with separately

- Visual fields and binocular overlap

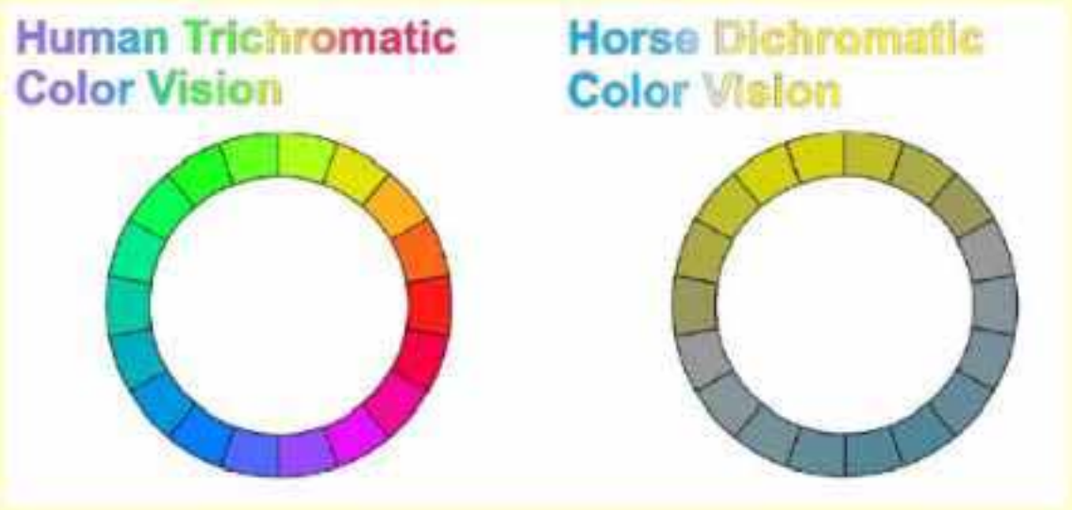
- Most mammals are good in the dark

- Daylight visual acuity is less good than ours

Vision and magnetoreception

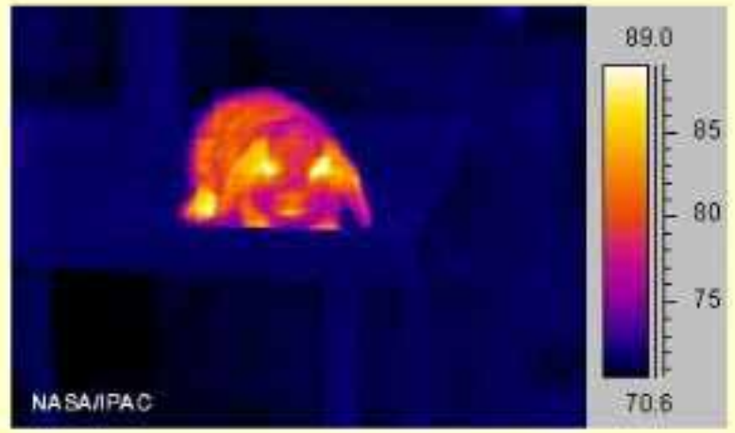
- Daylight visual acuity

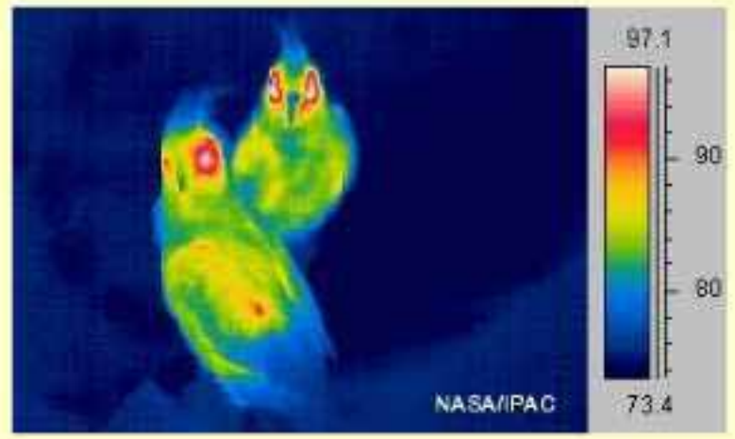
- Humans have trichromatic vision but many mammals are dichromatic



Vision and magnetoreception

Detecting ultraviolet and infrared



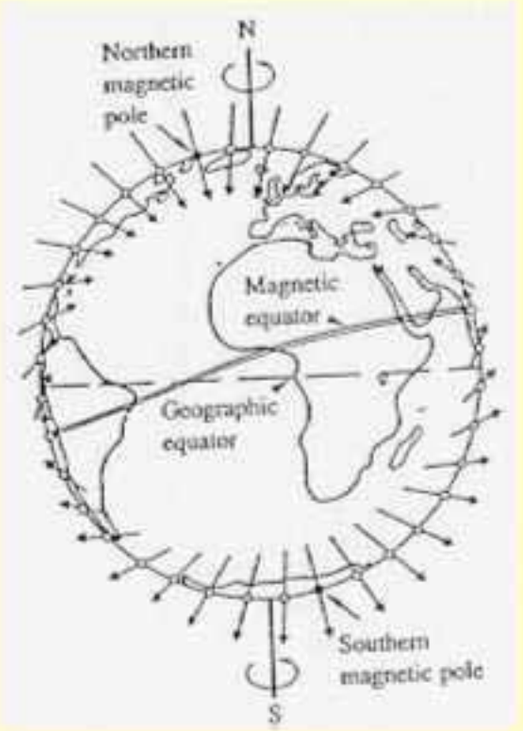


Vision and magnetoreception
- Magnetoreception

- Animals that navigate using detection of magnetic fields

- Polarity or inclination compass ?

-



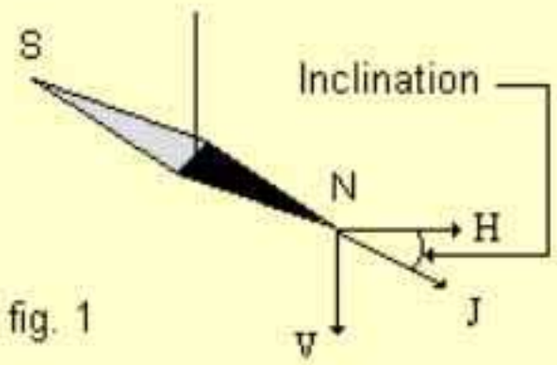


fig. 1

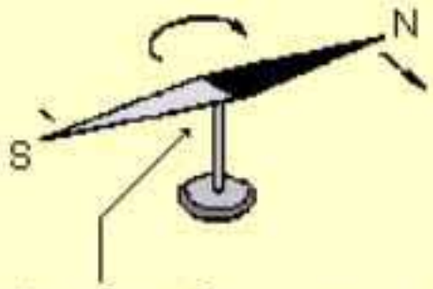


fig. 2

Vision and magnetoreception
- Magnetoreception

- Animals that navigate using detection of magnetic fields

- Polarity or inclination compass ?

- What about mammals ?

Vision and magnetoreception
- Magnetoreception

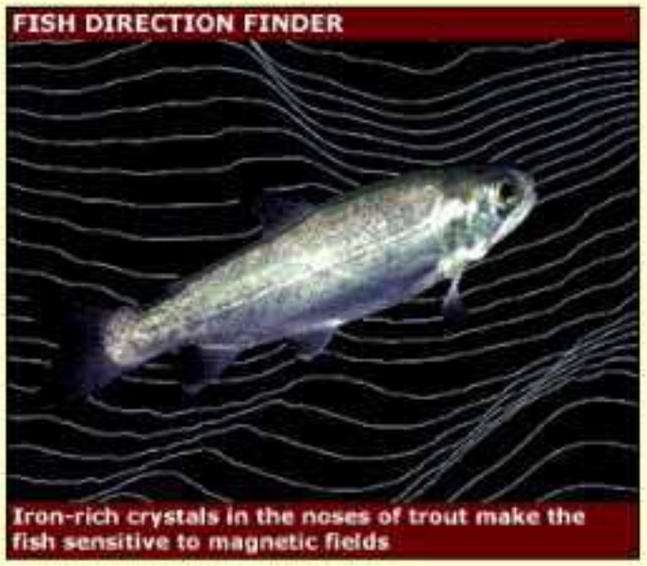
- The search for the magnetoreceptor:

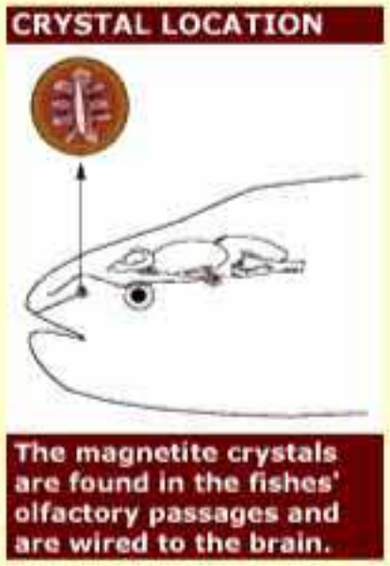
- Magnets in the head - Magnetite

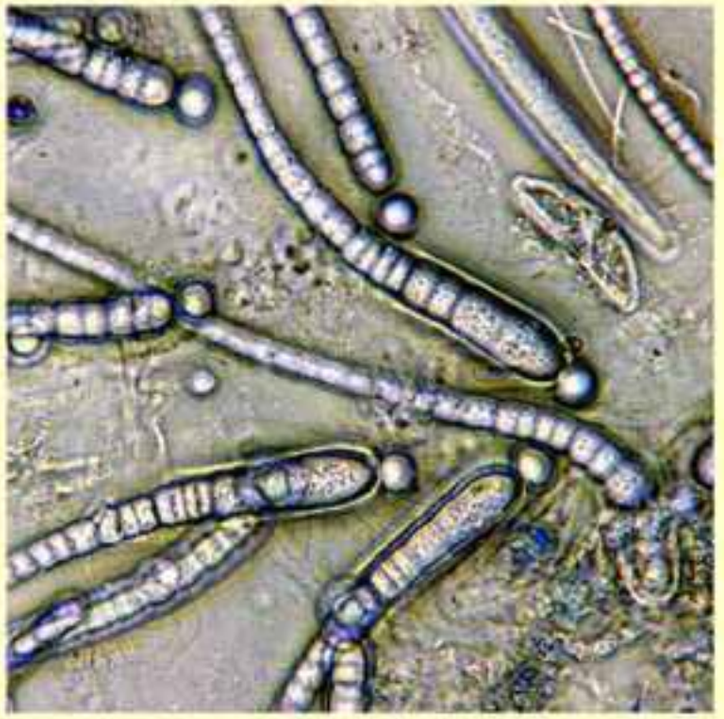
-

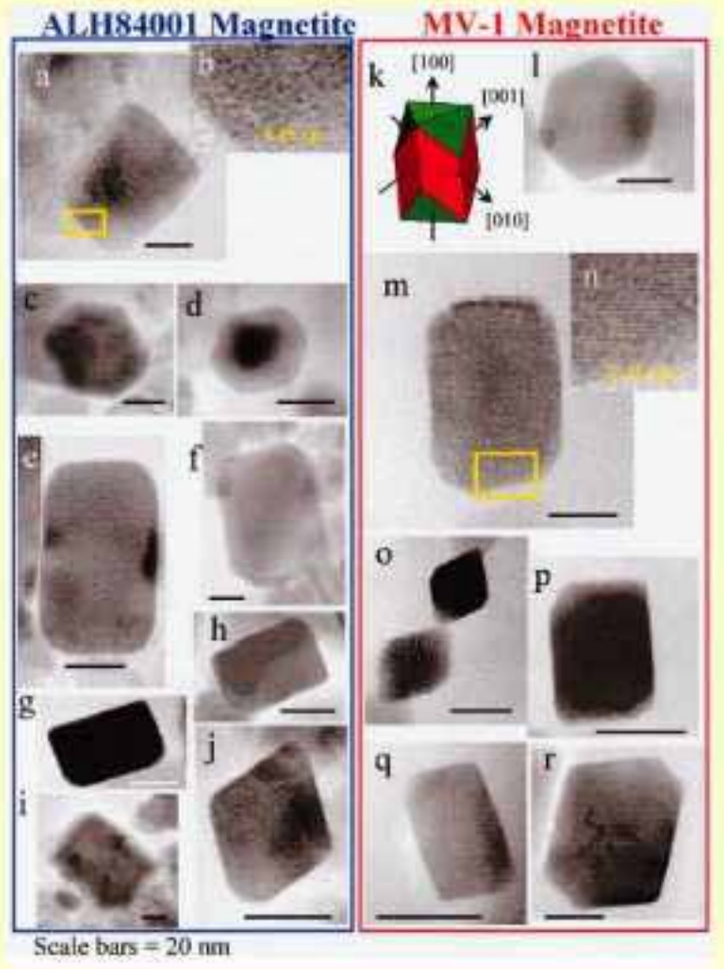
-

-









Vision and magnetoreception
- Magnetoreception

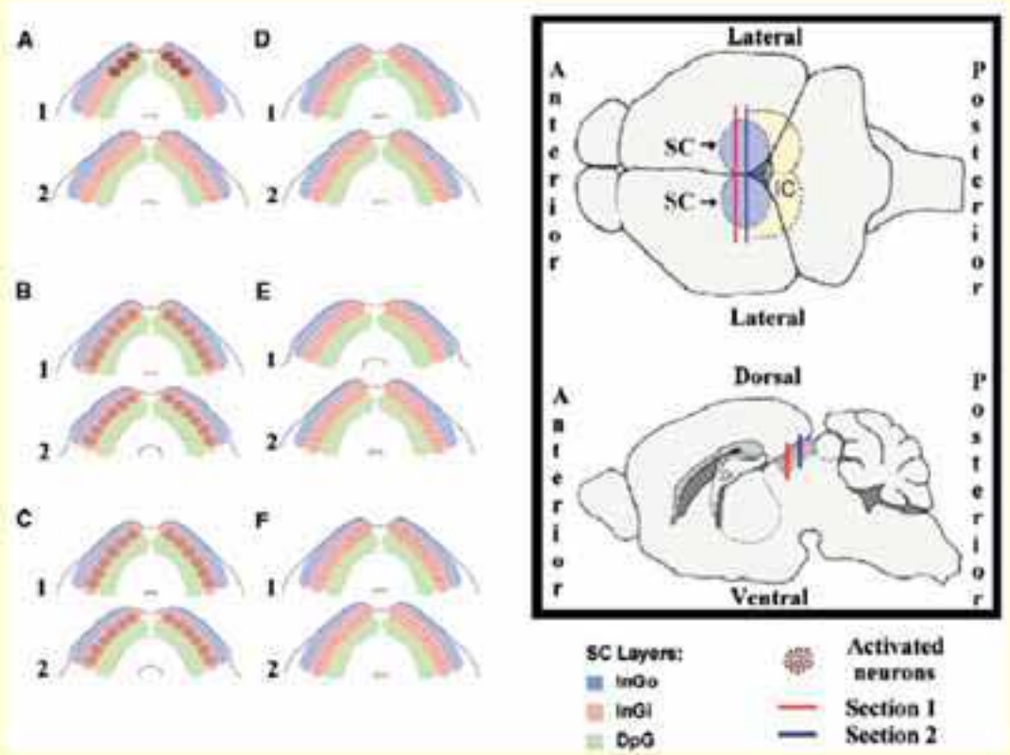
- The search for the magnetoreceptor:

- Magnets in the head - Magnetite

- Photoreceptors

-

-



Vision and magnetoreception
- Magnetoreception

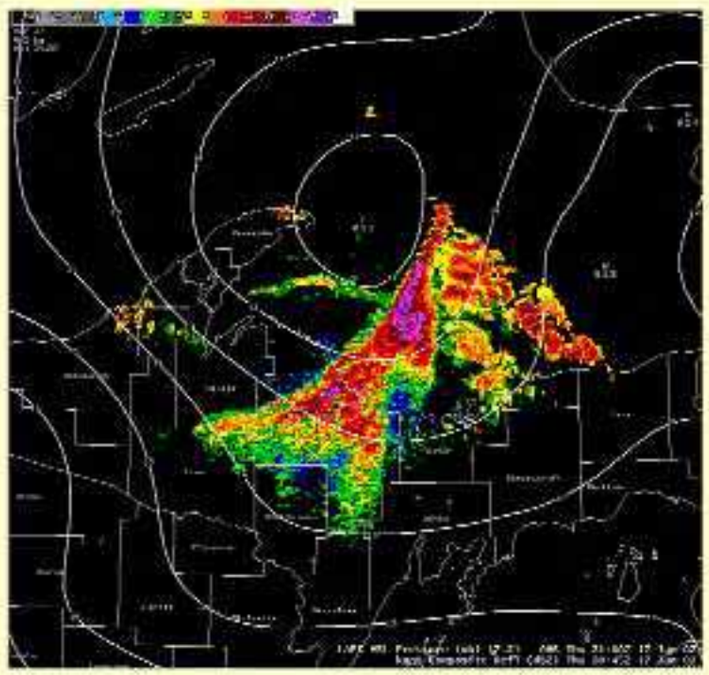
- The search for the magnetoreceptor:

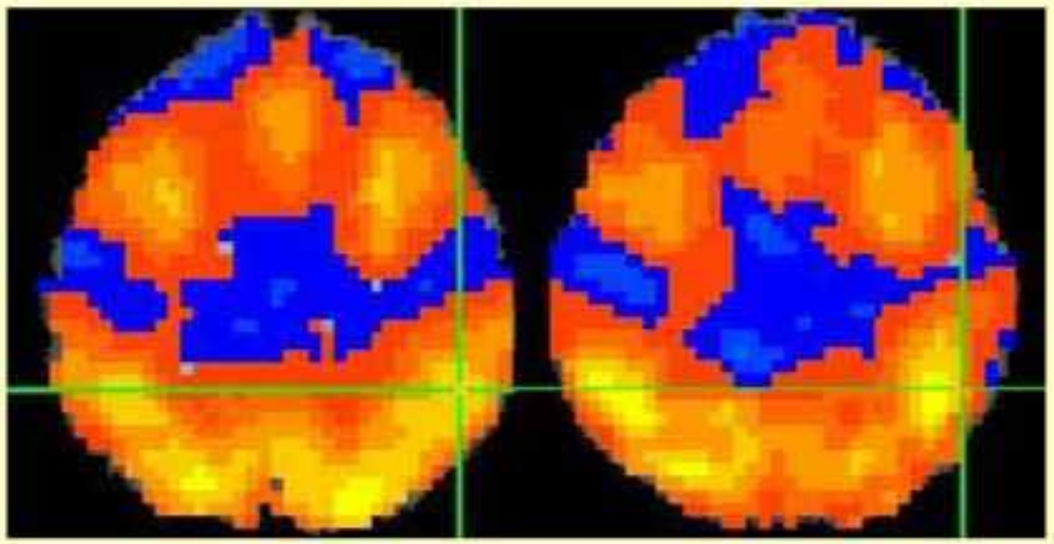
- Magnets in the head - Magnetite

- Photoreceptors

- Detecting storms and body electrical activity ?

-





Vision and magnetoreception
- Magnetoreception

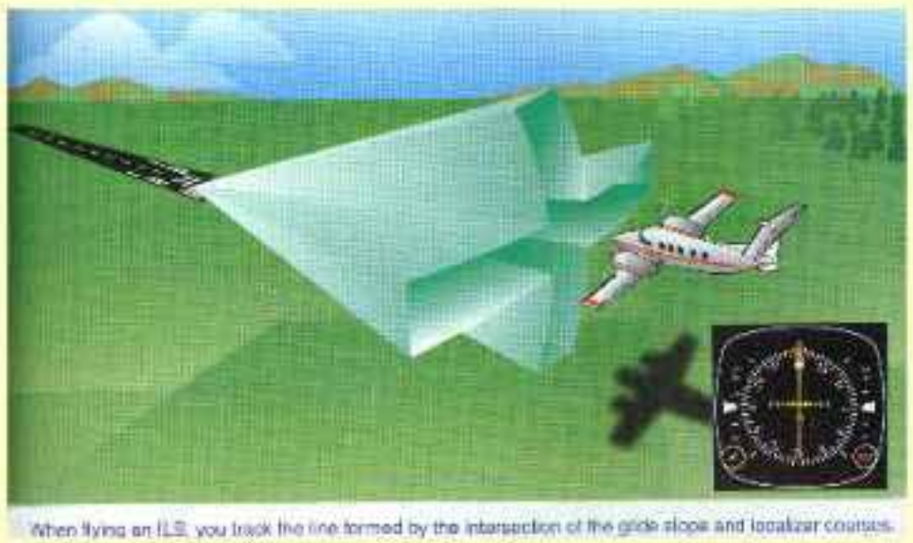
- The search for the magnetoreceptor:

- Magnets in the head - Magnetite

- Photoreceptors

- Detecting storms and body electrical activity ?

- How are magnetic fields experienced ?



When flying an ILS, you track the line formed by the intersection of the glide slope and localizer courses.

Synaesthesia
- (syn = together + aesthesis = perception)

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-

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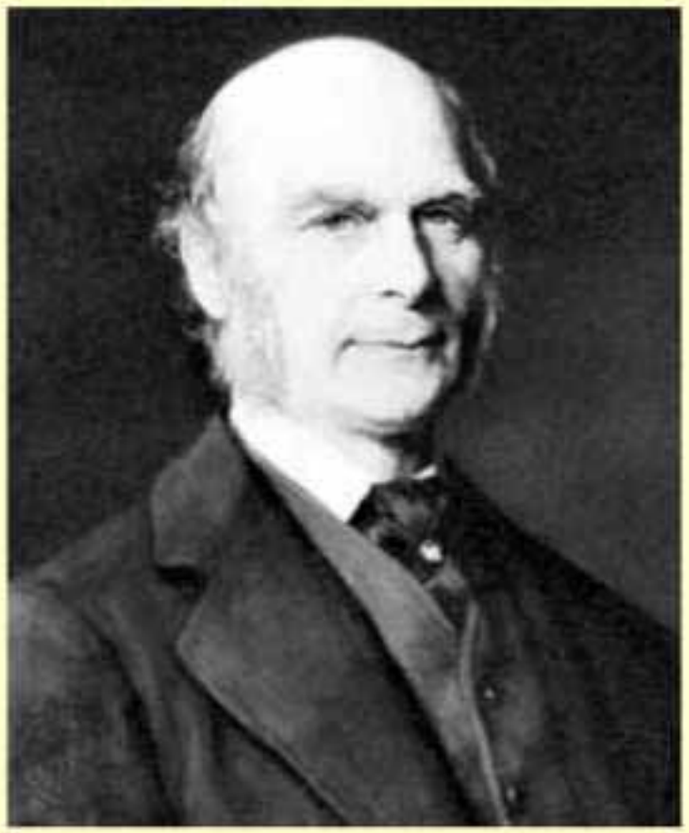


Galton

Synaesthesia
- (syn = together + aesthesis = perception)

- Seeing or hearing specific words, letters or numbers as colours

- " I've chosen and dumped girlfriends because of how their names tasted. The name Tracy tastes of flaky pastry. "

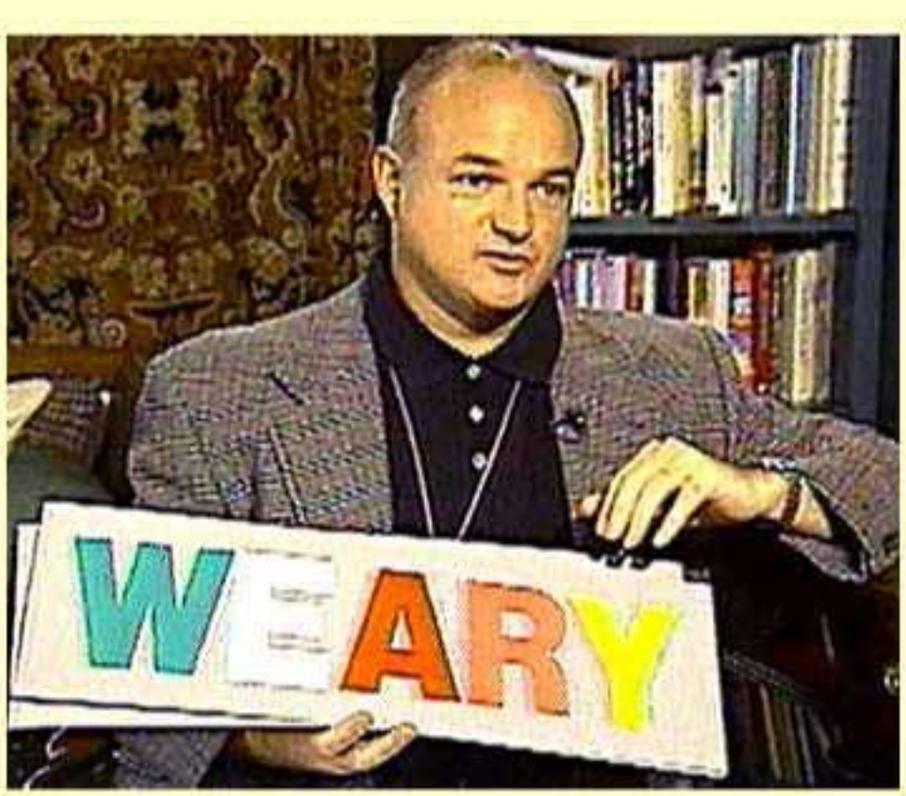
Synaesthesia
- (syn = together + aesthesis = perception)

- Seeing or hearing specific words, letters or numbers as colours

- Tasting shapes

-

-



Cytowic

Synaesthesia
- (syn = together + aesthesis = perception)

- Seeing or hearing specific words, letters or numbers as colours

- Tasting shapes

- Feeling musical instruments as touch in different body regions

-

Synaesthesia
- (syn = together + aesthesis = perception)

- Seeing or hearing specific words, letters or numbers as colours

- Tasting shapes

- Feeling musical instruments as touch in different body regions

- Affects between 1 in 200 and 1 in 20,000 individuals

Synaesthesia
- (syn = together + aesthesis = perception)

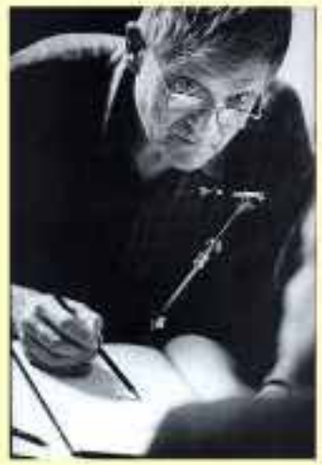
- Prevalent in artists (23% of 358 fine-arts students)

-

-

Nabokov

Scriabin



Hockney

Messiaen

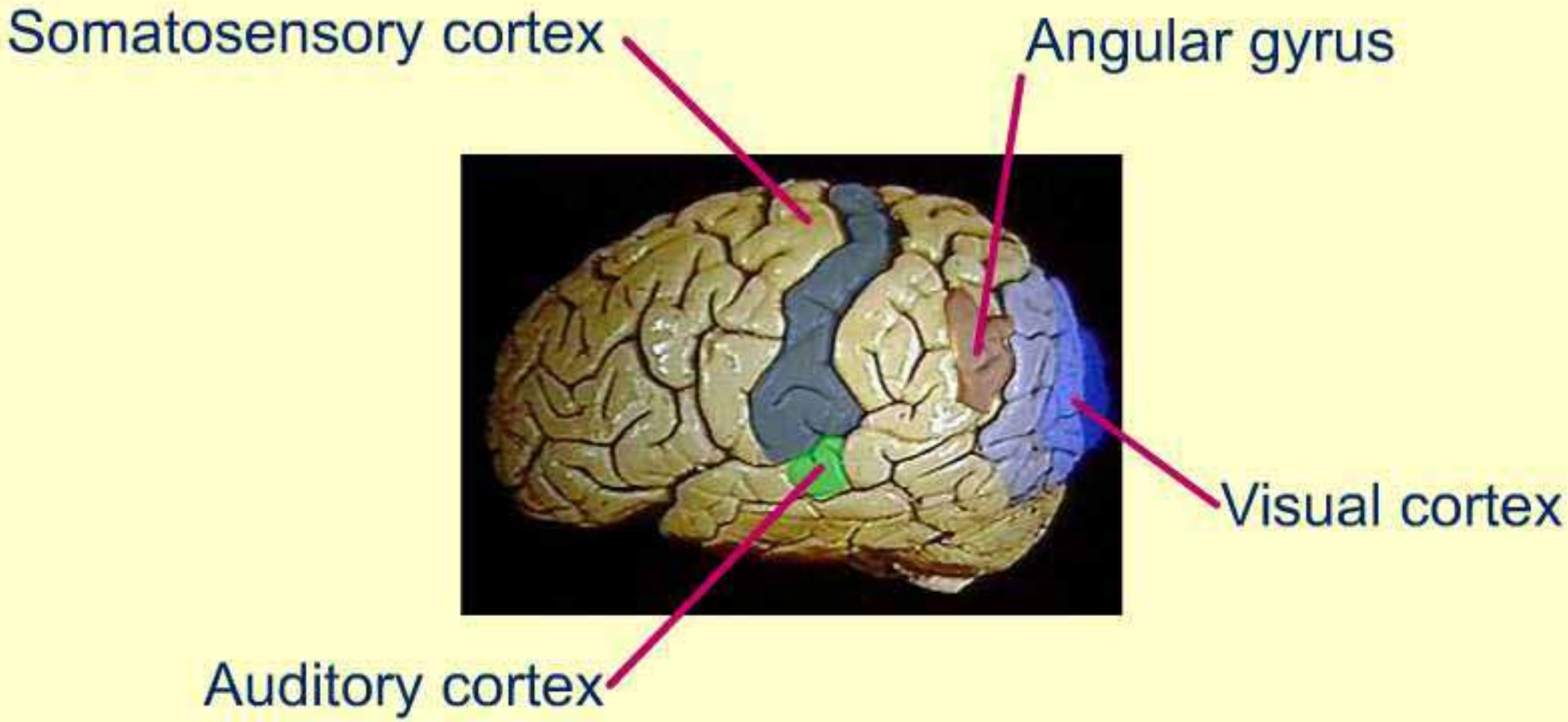
Synaesthesia
- (syn = together + aesthesis = perception)

- Prevalent in artists (23% of 358 fine-arts students)

- Probably caused by cross wiring between adjacent sensory maps

-

-



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- Prevalent in artists (23% of 358 fine-arts students)

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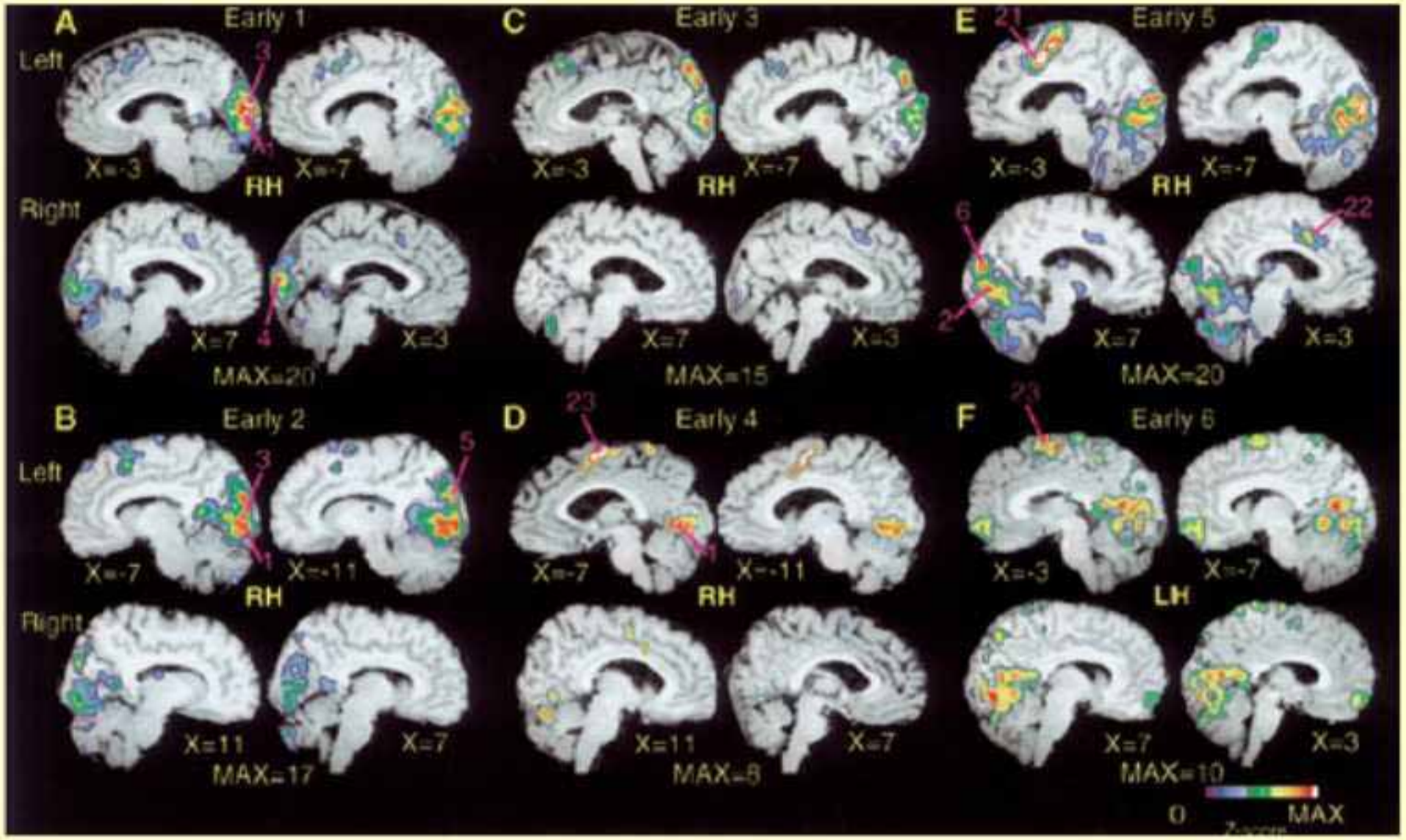
  stages of development

- Might some adult animals where vision is poor use visual parts of the brain to enhance experience of other senses ?

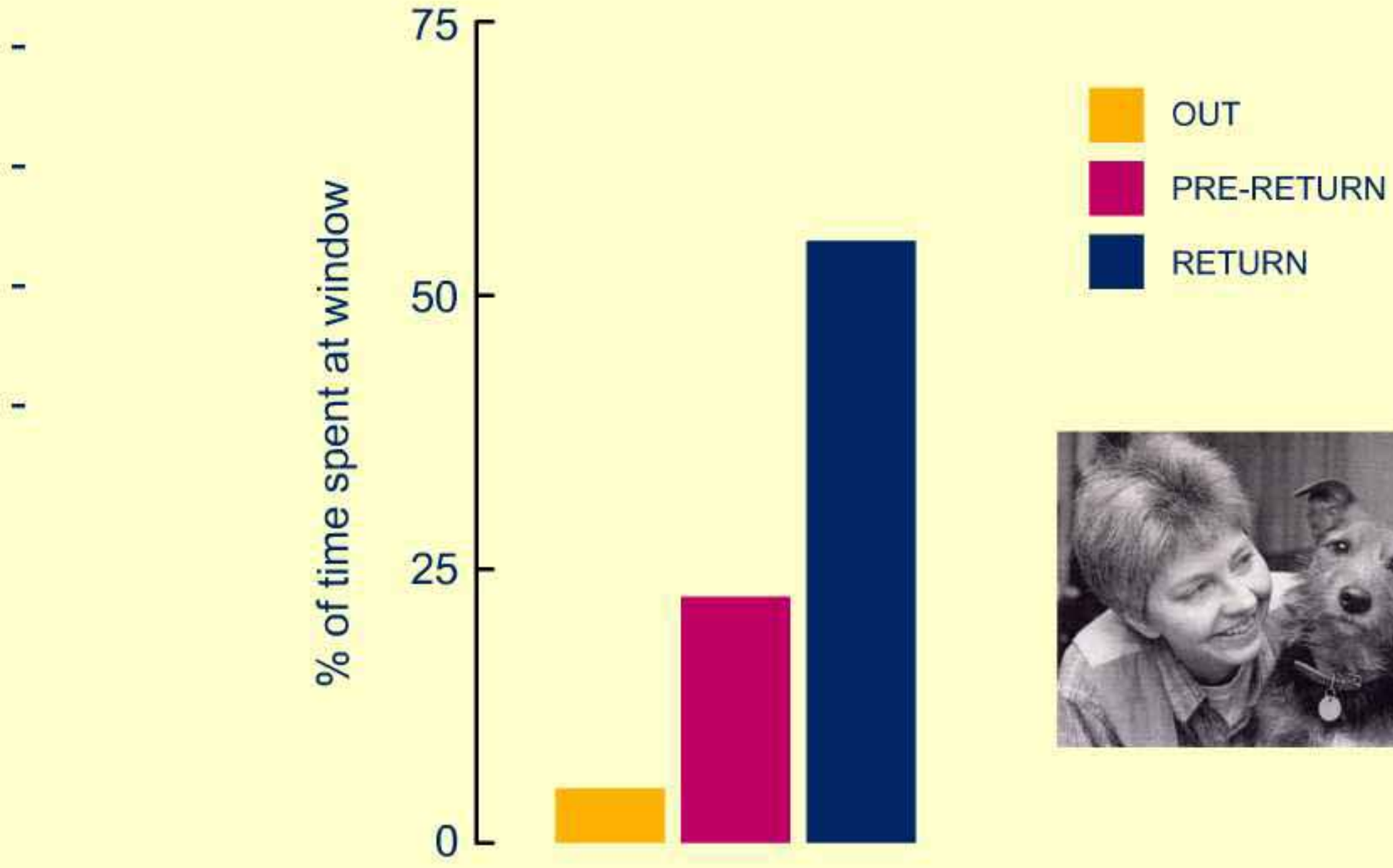
Synaesthesia
- (syn = together + aesthesis = perception)



Adaptive changes in early and late blind:
A fMRI sudy of Braille reading
Burton *et al* 2002

Is there a telepathic sense ?

- Sensing intention of companions or owners to return home



Is there a telepathic sense ?

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- In humans telepathic communication

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-

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Is there a telepathic sense ?

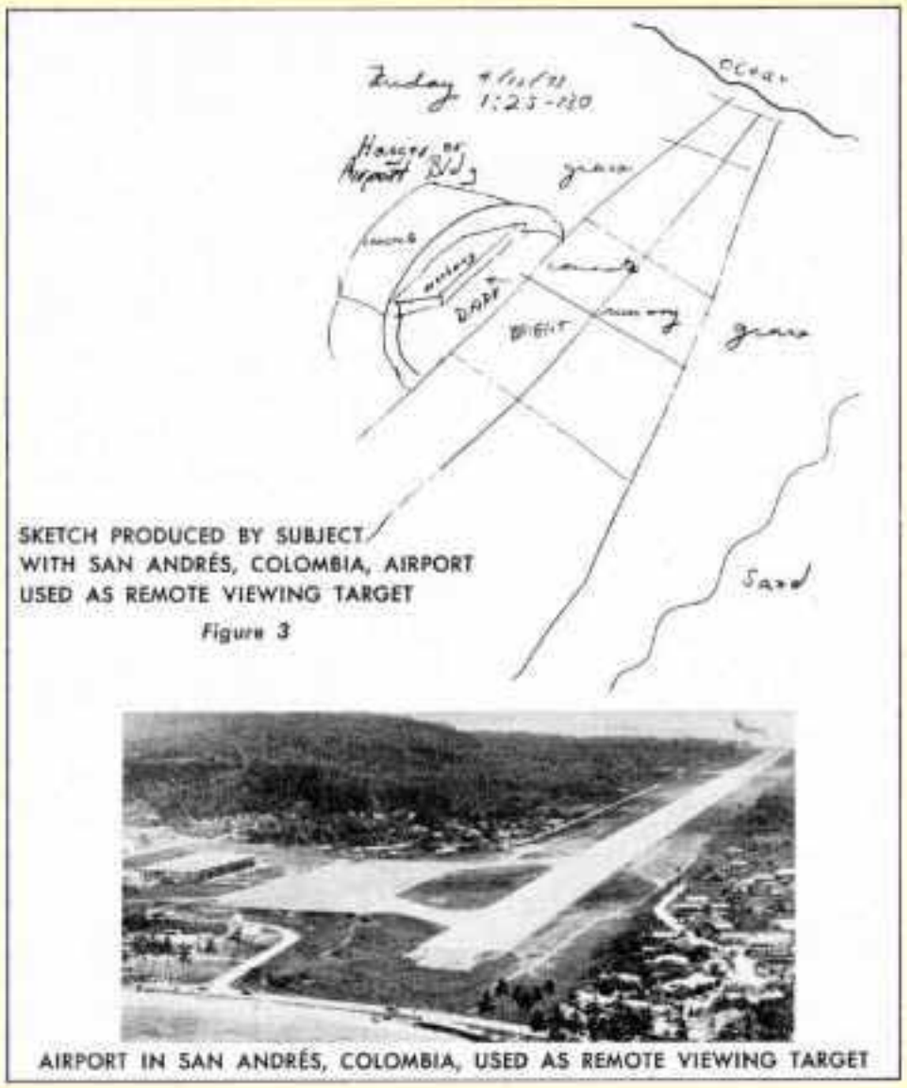
- Sensing intention of companions or owners to return home

- Sensing fear or suffering in absent offspring

- In humans telepathic communication

- Remote viewing

-



SKETCH PRODUCED BY SUBJECT WITH SAN ANDRÉS, COLOMBIA, AIRPORT USED AS REMOTE VIEWING TARGET

Figure 3

AIRPORT IN SAN ANDRÉS, COLOMBIA, USED AS REMOTE VIEWING TARGET

Is there a telepathic sense ?

- Sensing intention of companions or owners to return home

- Sensing fear or suffering in absent offspring

- In humans telepathic communication

- Remote viewing

- What is the form of energy and how is it detected ?

....and finally

- The world does indeed appear very different to other species

- Heightened or additional senses can explain many of their apparently supernatural abilities

- However, so far, not all !

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