Pathophysiology of the sense of smell and taste

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General Intro: Functional systems

- Nervous system has a complex role in analysis and synthesis of functional activity of organism
- Analysis of the environmental factors goes on in special systems – analyzers
- Each of them accepts only part of information from the environment - modality

Analyzers

- Peripheral part – receptor and peripheral afferent nerve fiber
- A few components of specific subcortical nuclei
- Cortical projection areas
- Information transmission to effectors via cortical association fibers/ other fibers (reflexes)

Analyzing systems

- Smell (chemical)
- Taste (chemical)
- Skin somesthetic (exterorecepting) – contain tactile (mechanical), termic, heat… and other pain sensing
- Interorecepting
- Propriocepting
- Stato-kinetic sensing
- Hearing (Telemetric)
- Vision (Telemetric)

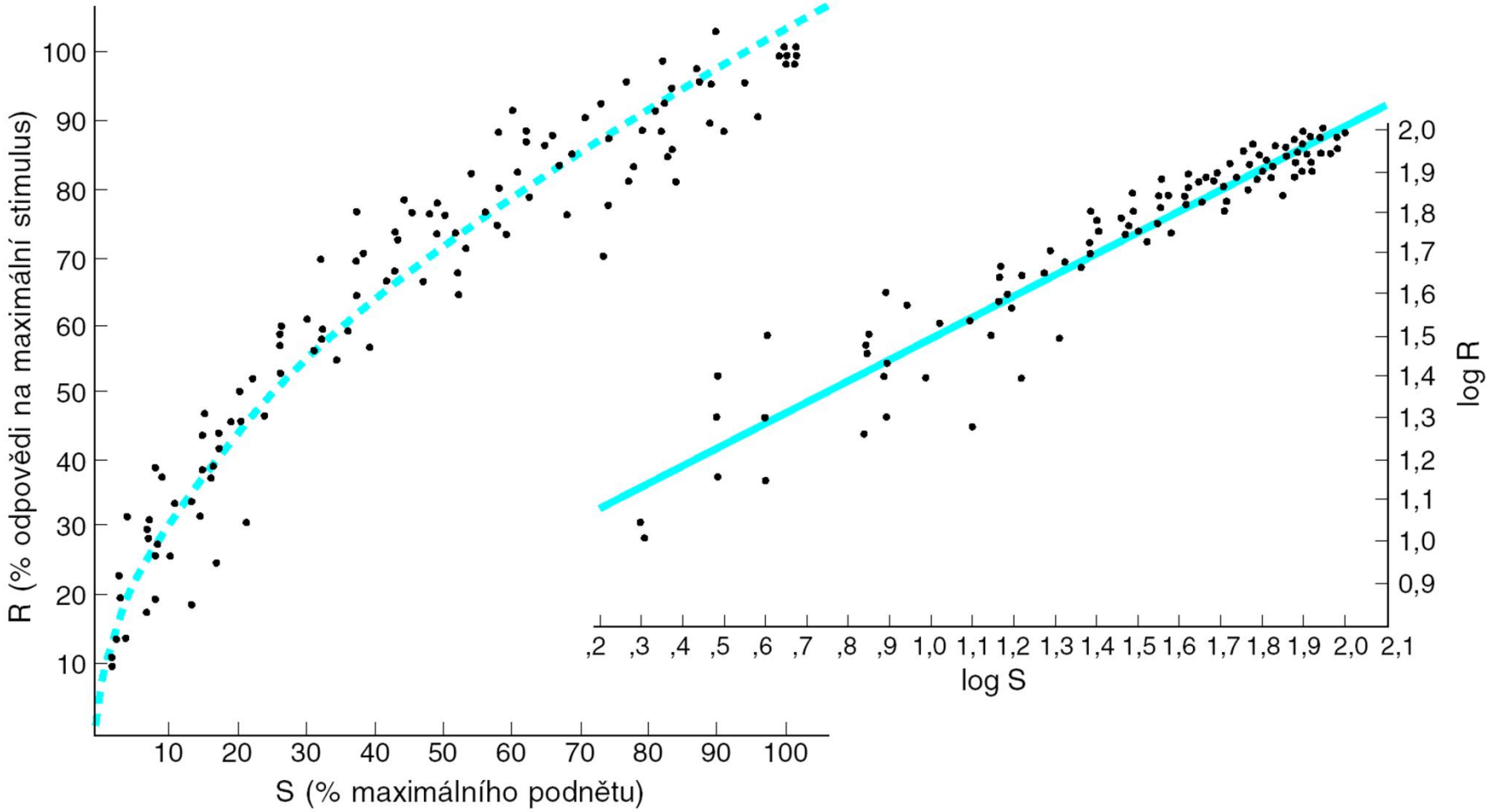
Function of receptors

- Receptors receive impulses from environment in various types of energy, which is transformed in them and propagates as a nervous signal in sensory nerves.

Threshold point of sensation

- Minimal (also Just Noticeable) difference of energy, which activates receptors and can cause a sensation
- Absolute threshold – person can feel that some stimulus came = detection
- Relative threshold – person can discriminate between two different stimuli = discrimination

Response (R) is function of stimulus intensity (S), R = f(S)



Obr. 5-5. Vztah mezi intenzitou dotykového podnětu (S) a frekvencí akčních potenciálů v senzorických nervových vláknech (R). Tečky znázorňují jednotlivé hodnoty u koček; jsou vyneseny do souřadnic lineárních **(vlevo)** a logaritmických **(vpravo)**. Rovnice vyjadřuje vypočítaný exponenciální vztah mezi R a S. (Reprodukováno se souhlasem z WERNER, G., MOUNTCASTLE, VB. *Neural activity in mechanoreceptive cutaneous afferents. Stimulus-response relations, Weber functions, and information transmission*. J Neurophysiol, 1965, 28, 359.)

Weber - Fechner law

- The most important property of this psycho-physical law is the ratio of two intensities and not absolute difference of these two intensities

Weber - Fechner rule

$R = k \log (S/ S_0)$

Golden age of psychophysics

(see: Weber-Fechner law,

Ernst Heinrich Weber, *1795–+1878)

Gustav Theodor Fechner,(*1801, Poland,+1887, Leipzig, Germany),

1850 – one day G. T. F. arrived to an “instant enlightenment” and knew, how to describe sensory perception in general. It took him another 10 year to formulate everything in a definitive book:

Elemente der Psychophysik (1860),

1878 – definition of median (= this is the value, dividing the cumulative distribution function in two halves)

Aside: on One Psychophysics Application, or On the Scoville Scale of Hot Chili Peppers…

Who was W. Scoville ?

1. Wilbur Lincoln Scoville, american pharmacist, (1865 – 1942), circa 3 generations after Fechner
2. William Beecher Scoville, american neurosurgeon, (1906 - 1984), another 2 generations
3. Brenda Milner, canadian psychologist, (1918 – present, will be soon over 100(!), born on the same day as Vernon Benjamin Mountcastle, 1918-2015), another 3 generations before to-day
4. William Beecher Scoville and Brenda Milner (1957). "Loss of recent memory after bilateral hippocampal lesions". Journal of Neurology, Neurosurgery and Psychiatry 20, (1): 11–21.
5. Patient H.M. - Henry Gustav Molaison (1926 – 2008), contemporary of Brenda Milner…

Scoville ratings of hot peppers

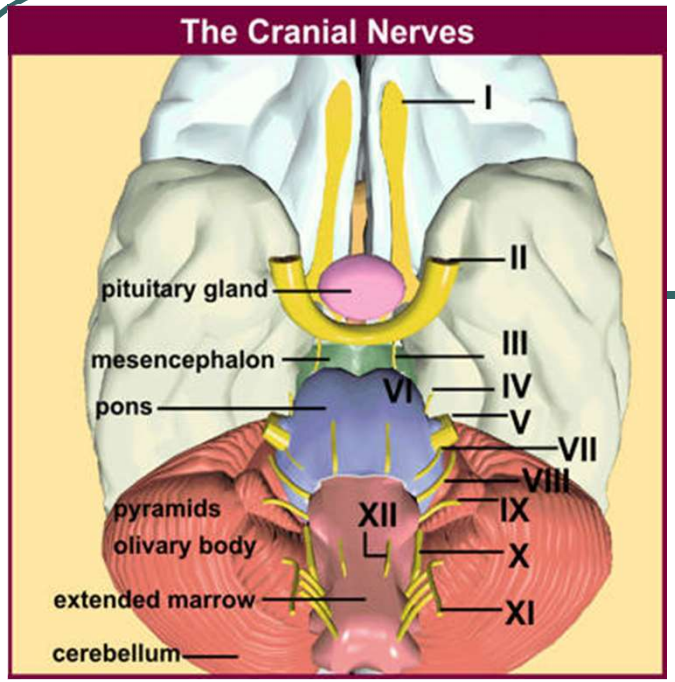
examples

3 000 000-6 000 000	Pepper spray
2 000 000	Trinidad Moruga Scorpion
1 850 000	Chocolate 7-Pot
1 600 000	Dorset Naga
1 450 000	Trinidad Scorpion Butch Taylor
1 200 000	Naga Viper, Trinidad 7 Pot Jonah
1 200 000	Satan's Strain Trinidad Scorpion Moruga
1 100 000	Naga Morich, Infinity Chili
1 050 000	Bhut Jolokia
850 000	Trinidad 7 Pot CARDI Strain
350 000 – 580 000	Red Savina Habanero
100 000 – 350 000	Habanero
50 000 – 100 000	Pepper Birds Eye, Piri Piri
30 000 – 50 000	Tabasco pepper
5 000 – 23 000	Serrano
5 000 – 10 000	Chipotle
2 500 – 8 000	Jalapeño, Tabasco sauce
1 000 – 2 000	Poblano
100 – 500	Pimento

Scoville ratings of chemicals (Scoville heat units)	substance examples
16,000,000,000	Resiniferatoxin
5,300,000,000	Tinyatoxin
16,000,000	Capsaicin
15,000,000	Dihydrocapsaicin
9,200,000	Nonivamide
9,100,000	Nordihydrocapsaicin
8,600,000	Homocapsaicin
160,000	Shogaol (dehydr. ginger oil)
100,000	Piperine (black pepper alkaloid)
60,000	Gingerol (ginger oil)
16,000	Capsiate

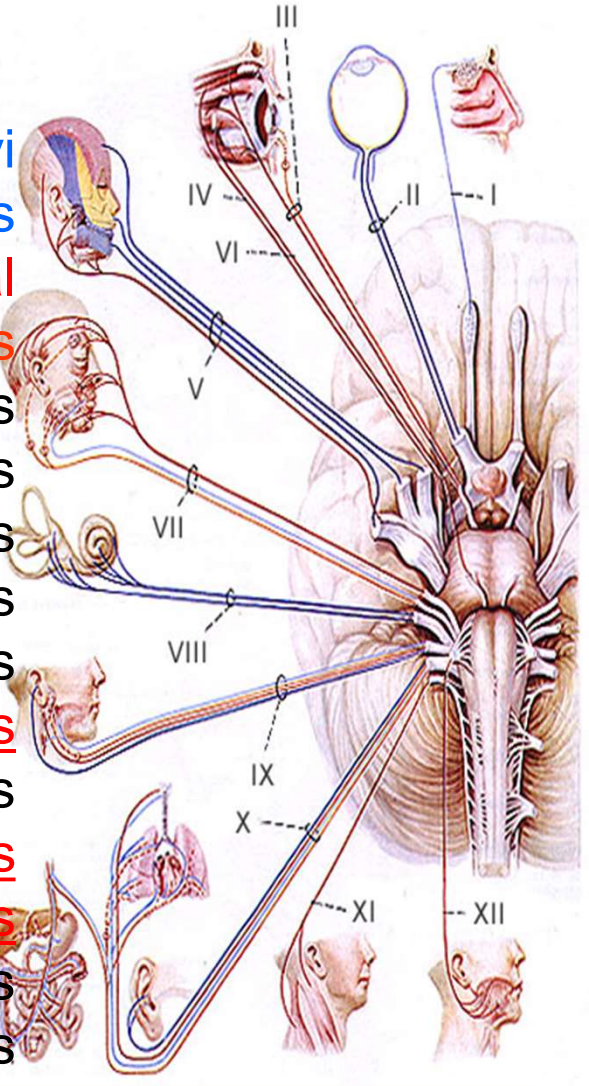
Smell

- Sense of chemical molecules from the environment is a basic characteristic of living organisms
- Chemical signals activate not only these specialized receptors but can also activate non-specifically mucosa (stronger stimuli)
- Sensitive are also chemoreceptors near by presoreceptors in blood vessels



12+ cranial nerves

Nervi
Craniales
No.0 -Vomero–Nasal
I - Olfactorius
II - Opticus
III-Oculo-motorius
IV - Trochlearis
V - Trigeminus
VI - Abducens
VII - Facialis
VIII – Vestibulo-cochlearis
IX – Glosso-pharyngeus
(vii, ix, x)Tractus solitarius, X - Vagus
XI - Accessorius
XII - Hypoglossus



Anatomy and function of the olfactory system

- The olfactory system of human covers approximately 2,5 cm^2 of nasal mucosa
- Covers upper third of septum and superior turbinated bone
- Proper olfactory epithelium consists of olfactory cells and supporting cells

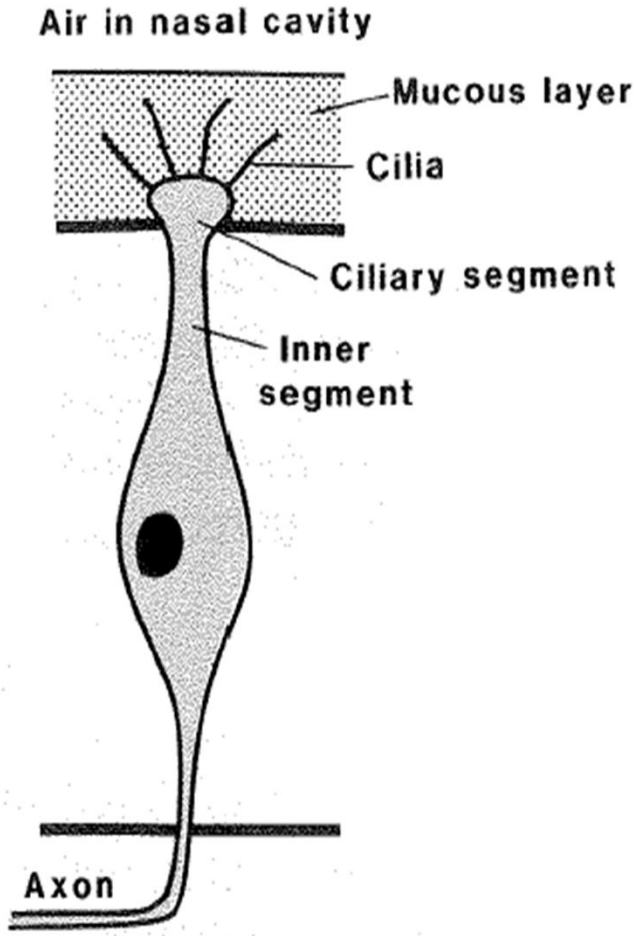
Anatomy and function of the olfactory system

- There is more than 10 milions of the olfactory cells. They look like modified bipolar neural cells. They are spindle - shaped with a large spherical nucleus surrounded by a small amount of granular protoplasm, and possessing two processes (axons), of which one runs outward between the columnar epithelial cells, and projects on the surface of the mucous membrane as a fine, hair-like process, the olfactory hair.

Anatomy and function of the olfactory system

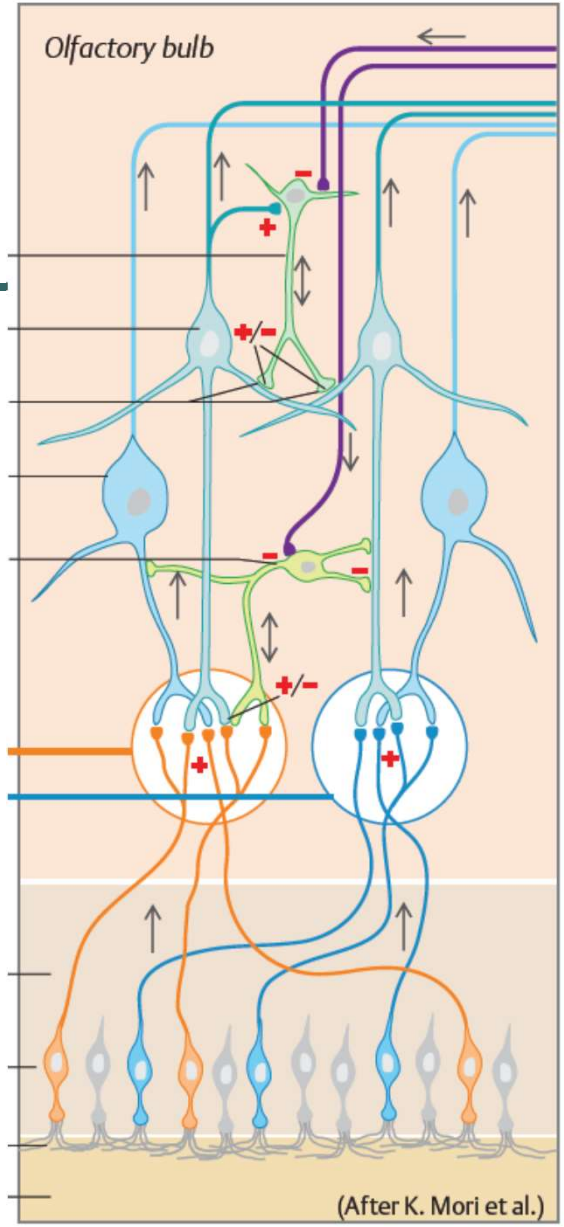
- The other or deep process runs inward, frequently beaded, nerve-fibre, and it is in connection with one of the terminal filaments of the olfactory nerve.
- This is a location of the receptor potentials which are created after excitation of olfactory hair with an inhaled substance

Olfactory receptors



VERTEBRATE OLFACTORY RECEPTOR

Structure and function of olfactory system



Anatomy and function of the olfactory system

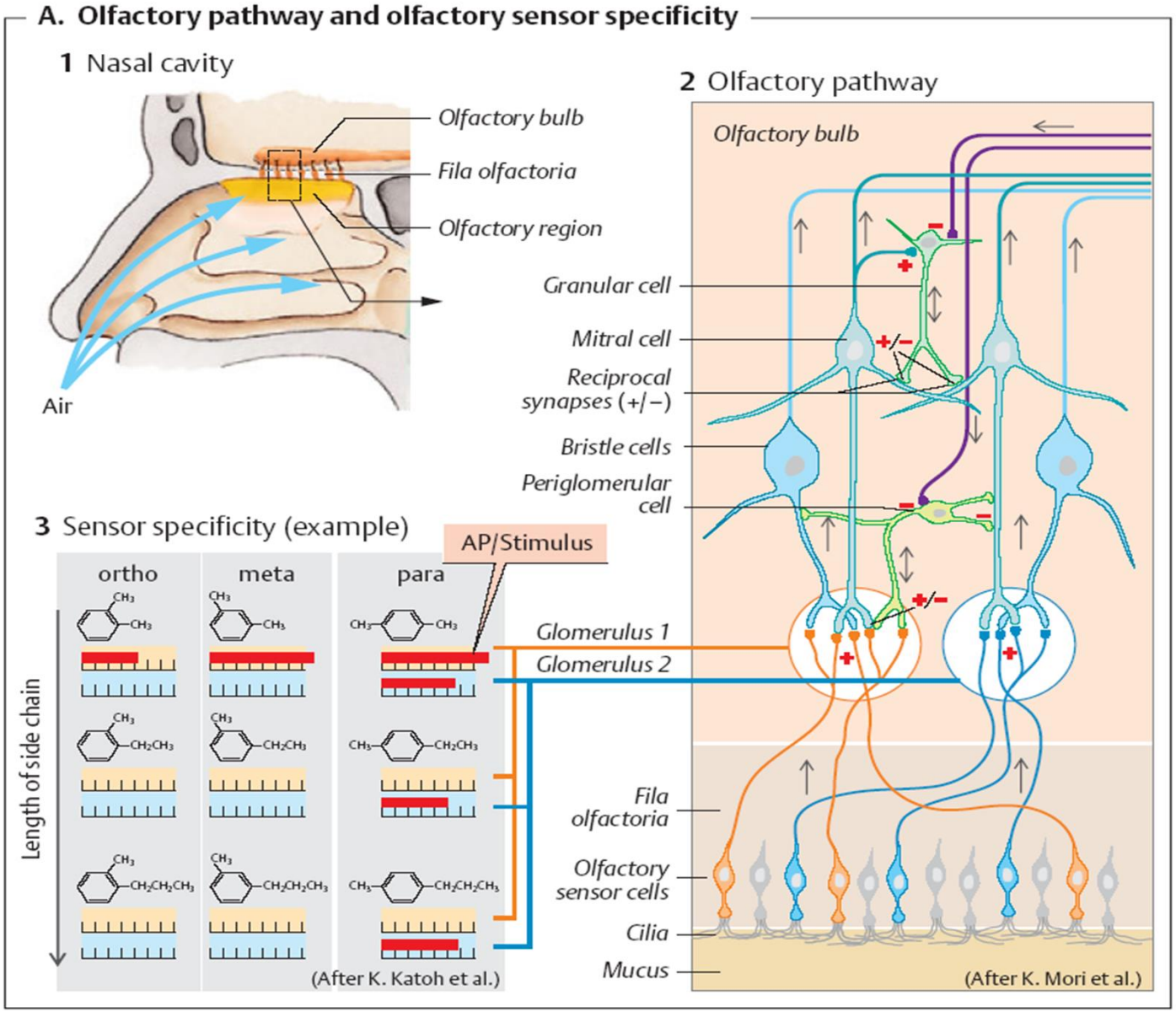
- Fila olfactoria go into small spaces in the cribriform plate of the ethmoid bone into skull cavity and follow into bulbus olfactorius, this way they connect action potential to dendrites of mitral cells in special glomeruli - glomeruli olfactorii.

Anatomy and function of the olfactory system

- Neurites of mitral cells go into tractus olfactorius and then into basal olfactory cortex (area prepyriformis, upper part of amygdaloid complex and peri-amygdaloid cortex).
- Fibres from the other cells, e.g. bristle cells of olfactory bulbus go across commisura anterior into opposite bulbus olfactorius when some fibres go into substantia perforata anterior.

(comment: pathway crossings…)

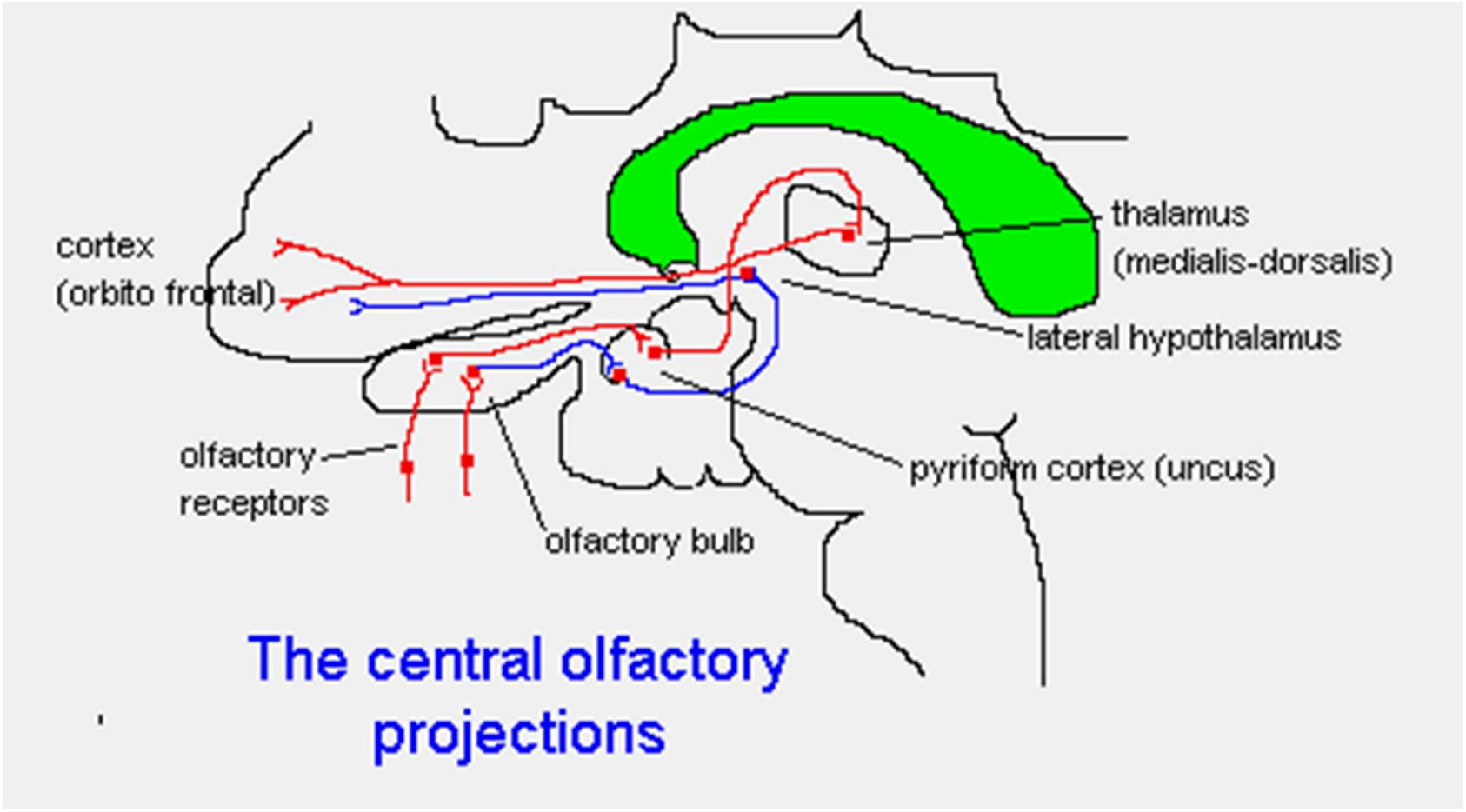
Smell


A. Olfactory pathway and olfactory sensor specificity
1 Nasal cavity
Olfactory bulb
Fila olfactoria
Olfactory region
Air
2 Olfactory pathway
Olfactory bulb
Granular cell
Mitral cell
Reciprocal synapses (+/−)
Bristle cells
Periglomerular cell
3 Sensor specificity (example)
AP/Stimulus
ortho
meta
para
Length of side chain
Glomerulus 1
Glomerulus 2
Fila olfactoria
Olfactory sensor cells
Cilia
Mucus
(After K. Katoh et al.)
(After K. Mori et al.)

Anatomy and function of the olfactory system

- Prepyriform cortex is an olfactory center and other connections go into entorhinal cortex and hippocampus.
- From primary olfaction centers go striae medullaris thalami and fasciculus telencephali medialis into specific parts of limbic system.

Olfactory tract



Activation of olfactory receptor

- Gas molecules, mixed with an inhaled air
- Water-soluble molecules are dissolved in the thin layer of mucus, which covers olfactory mucosa. There are hair-like processes of dendrites of olfactory cells.

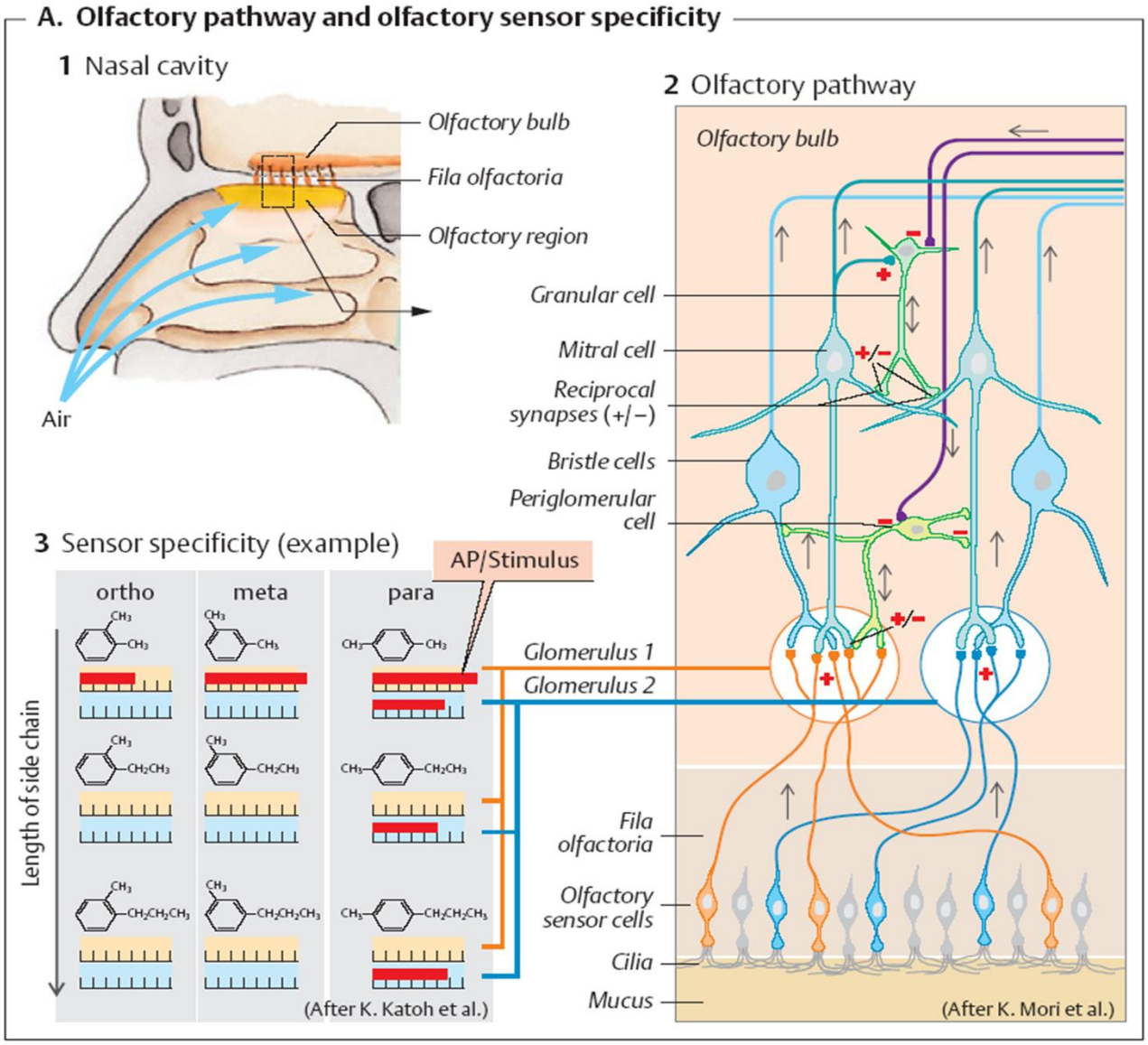
Sensitivity for the olfactory stimuli

- In dog – olfactory sense is 6-8 orders more sensitive (see discrimination) than in human

Sensitivity for the olfactory stimuli

- Sensitivity of olfaction depends on components of chemical molecule (e.g. on number of C atoms in molecule of organic acids) and also on its concentration in an inhaled air

Smell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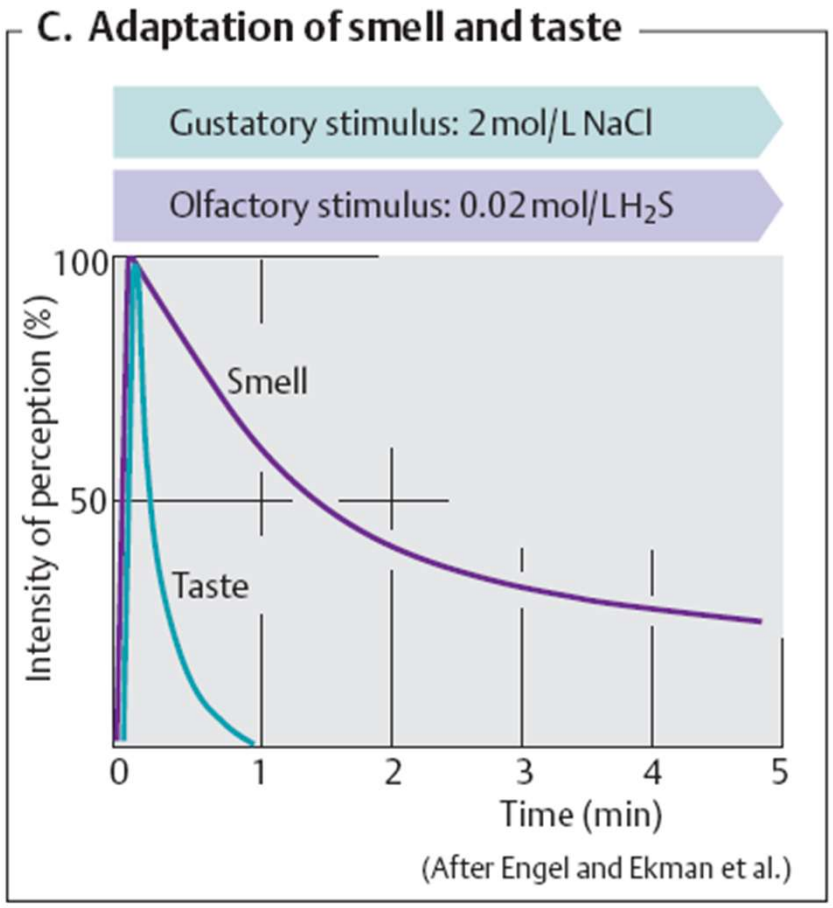
Sense for the olfactory stimuli

- Human can distinguish 2000-4000 different smells; intensity differences smaller than 30% in (inter-individual) average we are unable to distinguish
- Typical sign is also that olfactory sensation is the strongest in the beginning and then goes down, even though the concentration of substance is the same in the inhaled air all the time.
- It is an adaptation to the stimulus.

Adaptation of smell and taste in time



Investigation of smell

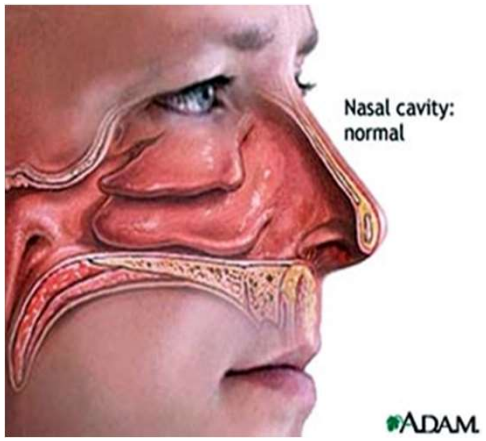
- Subjective quality
- Test UPSIT (University of Pennsylvania Smell Identification Test) – patient tries to distinguish between different kinds of smells, which are available as scratching panels

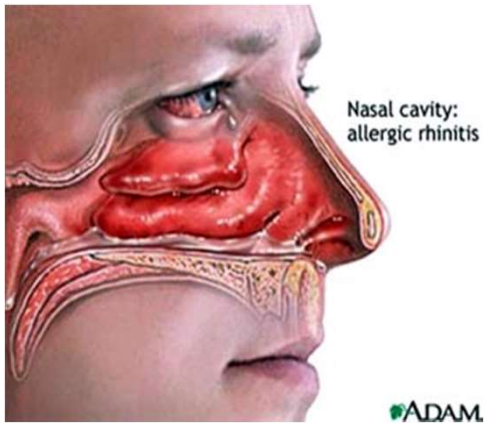
Investigation of smell

- Objective quality (?)
- Olfactometry – investigation of smell using evoked potentials
- SPECT – change in blood perfussion of different areas in brain depending on olfactory stimulation.

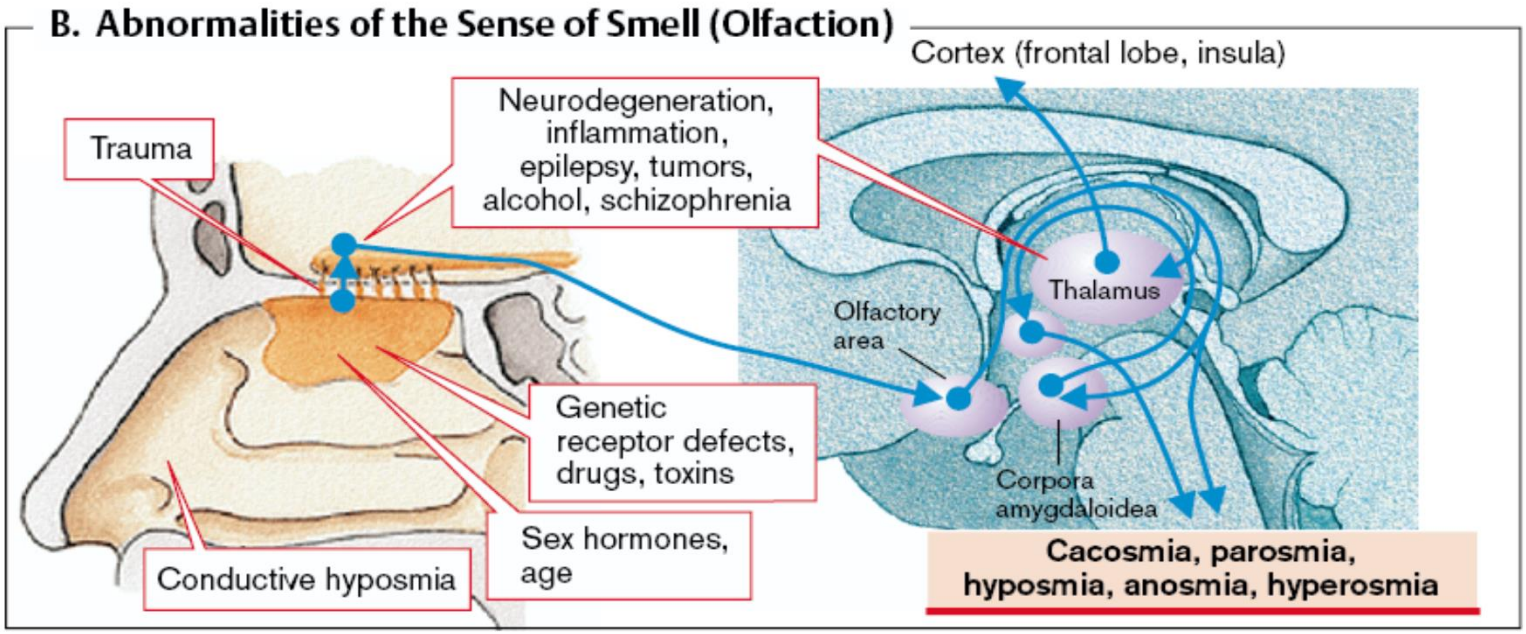
Smell disorders

- Hyposmia – reduced
- Anosmia – absent
- Hyperosmia – increased sensitivity





Abnormalities of olfaction



Anosmia and hyposmia

- intermittent – based on oedema of nasal mucosa
- Mechanical blockage in airways (deviation of nasal septum, adenoid hyperplasia, polypous changes, tumors)
- Albinism – absent of pigmentation in epithelial olfactory cells, it is not possible to recognize a smaller differences in smell signals

Hyperosmia

- Irritation of central part of olfactory system
- Pregnancy
- Atherosclerosis of CNS
- Aura before an epileptic or migrenous attack

Qualitative disorders of smell

- Parosmia – objective, patient can smell given odorant (fragrance) differently than healthy person or subjective/ hallucinatory when patient can smell fragrance which does not exist (dysosmia)
- When patient is aware/ conscious that it is unusual situation, is called pseudo-hallucination, when comparing with olfactory hallucinations.
- Cacosmia – a special type of parosmia when smell feeling is unpleasant

Disorders of olfactory tract

- Olfactory bulbus and tract – unilateral disorders – patologic processes in anterior region of the skull – tumors, abscesses of anterior lobe, fractures, osteomyelitis of base of the skull

Unilateral disorders of cortical part of olfactory analysator

- Usually they are not diagnosed because of each cortex centrum has a connection with afferental parts of unilateral olfactory analysator and also with bilateral olfactory region

Unciform crisis

- Triggering of cortex in parts of olfactory analyser
- Attacks of deceptive sensations of unpleasant smells like burning tar/ tyres, spoiled egs (H2S) etc.
- Connected with gustatory pseudo-hallucinations
- First sign of tumours of anterior and basal parts of temporal lobe
- Accompanies epilepsy paroxysms in temporal epilepsy

The sense of taste

- Complex and extremly subjective sense quality
- Compounded from more signals as an olfaction, mechanical and temperature characteristics accompanied with pain feeling
- Involved by sense of smell, eyes, and sound

Receptors

- Taste receptors in mouth and nasal cavity can receive perception of taste signals and can help in working with this information
- Can distinguish taste of different aroma
- Registr consistence of food and drink; we can distinguish between fluid and stif compounds of meal, temperature and adstringent effect etc.

Perception of the sense of taste

- In natural conditions it is not possible to accept only taste qualities. We also accept a smell qualities together with taste qualities.
- Treshold for taste signals are higher than for the sense of smell due to lower sensitivity of taste receptors.

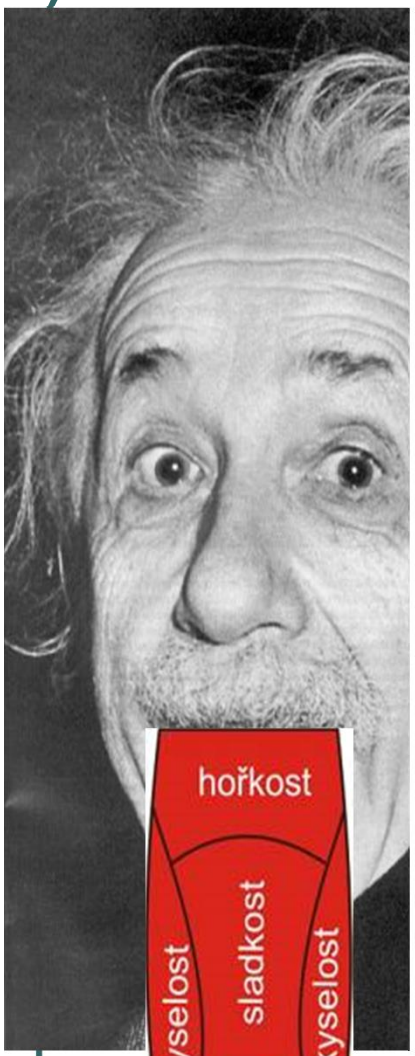
Perception of the sense of taste

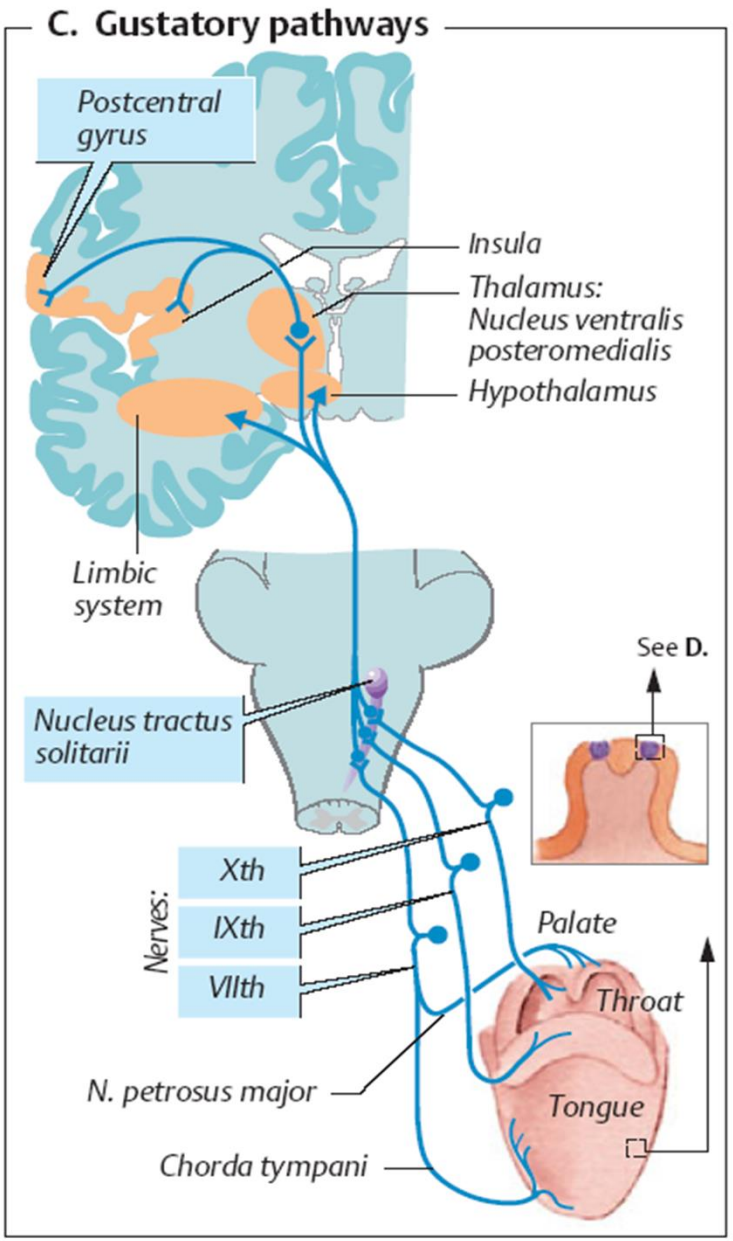
- For activation of taste receptors we need aproximately 20 000 x more molecules than in activation of smell receptors
- Receptors in tongue area, palate and throat are activated by soluble substances contained in food and dring

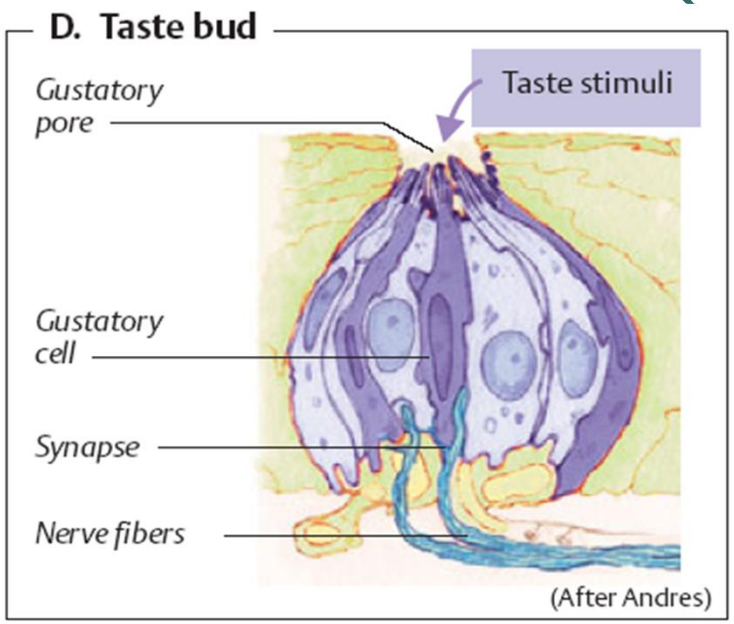
Taste sensations

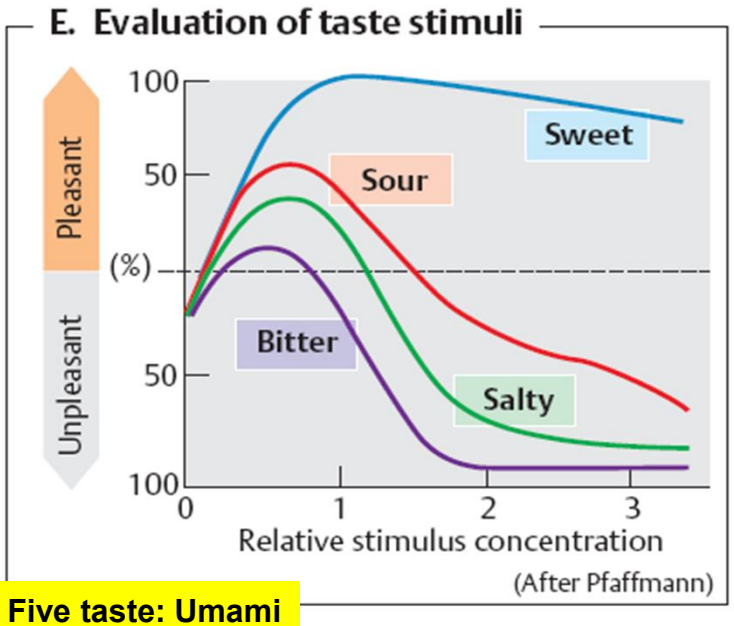
- 4 basic – salty, sweet, sour, bitter
- 5. taste modality-“umami“ responses to taste of glutamate, described by Japanese authors

A. How to stick out the tongue (After Einstein)









Five taste: Umami

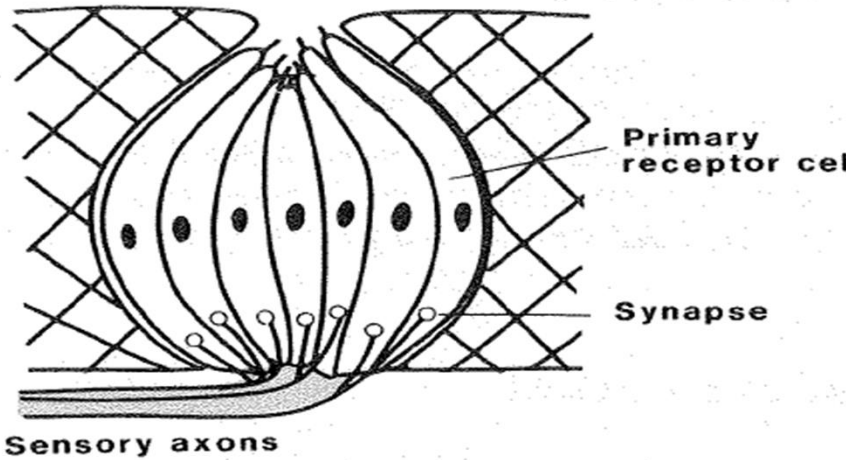
B. F. Sensors: salty-Na^+ , sour-H^+, sweet-?, bitter>50 alkaloid receptors, umami-mGluR4

The sensation of taste

- Depends on chemical components of substance
- sour –H+ionts
- Salty –anorganic salts ionts
- Sweet and bitter – organic compounds, some anorganic (salts of Pb- sweet; salts of Mg, Ca and NH4+ – bitter)

Taste bud

- About 10 000
- Also containe receptors for tactile, temperature and pain feelings with olfaction create a complex of the sense of taste.



VERTEBRATE TASTE BUD

Taste bud

Taste bud

- Each contains 20-25 neuroepithelial taste cells which are surrounded by less differentiated supporting cells as an reserve elements which can supply degenerating and dying taste cells
- Taste cells are continously regenerating cells, each of them lives about 200-300 h.

Taste bud

- Dissection of nerves fibres leads to the atrophy of the taste bud and its absence
- After their regeneration we can see inervation of the epithelium and also differentiation of the taste bud
- They are flask-like in shape, their broad base resting on the corium, and their neck opening by an orifice, the gustatory pore, between the cell of the epitelium.

Gustatory pathways

- The peripheral end end of the cell terminates at the gustatory pore in a fine, hair-like filament, the gustatory hair.
- The central process passes toward the deep extremity of the bud, and there ends in a single of bifurcated varicose filament, which create synapsis with the ends of gustatory nerves.

Gustatory pathways

- Taste receptors are inervated by fibres with slow conduction (diameter 4-6 μm)
- Anterior part 2/3 - n. facialis
- Posterior part 1/3 mainly n. glossopharyngeus
- Root of the tongue, pharynx and epiglotis - n. vagus

Gustatory pathways

- Gustatory fibres of VII.n. have first neuron in ganglion geniculi, IX.n. in ganglion petrosum and X.n. in ganglion nodosum
- Transmit informatiom into medulla oblongata where they connect and make a tractus – tractus solitarius.
- In nc. tractus solitarii ends first neuron of gustatory tract and fibres go by lemniscus medialis into thalamus.

Gustatory pathways

- In ncl. arcuatus thalami they switch over and lead fibres into border of parietal and temporal cortex where they end in operculum and insula.

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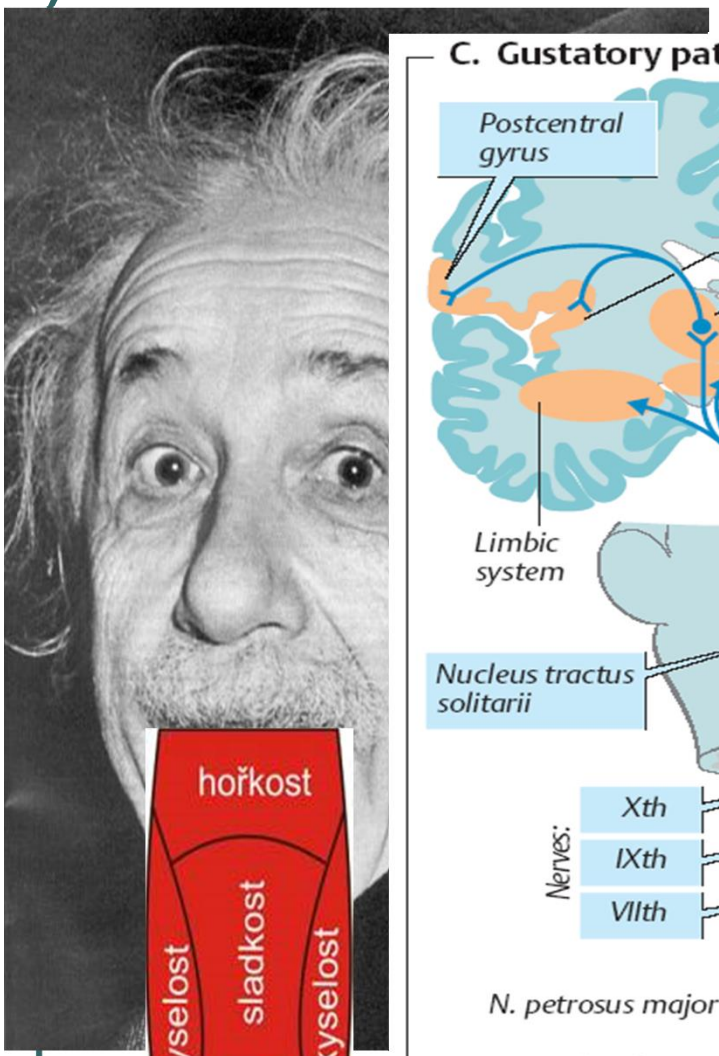
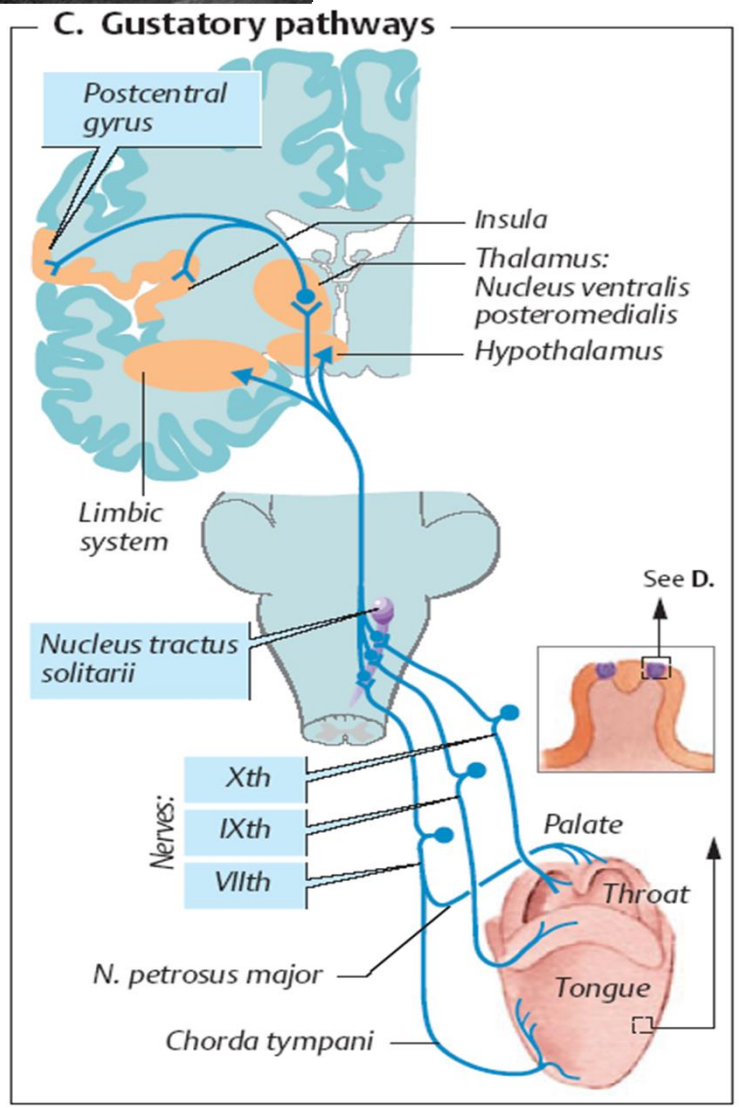
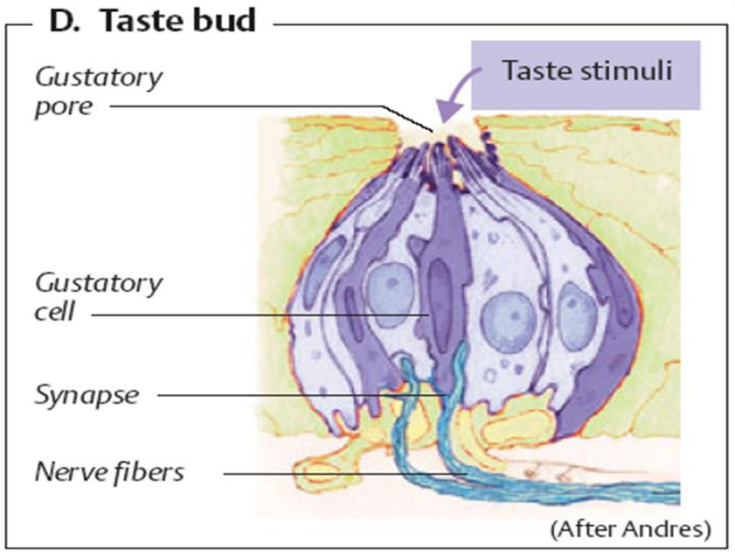
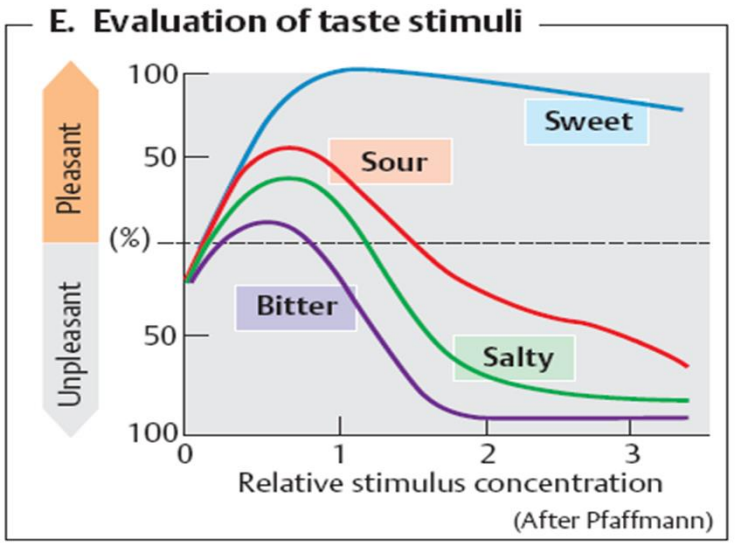








Five taste: Umami

B. F: Sensors: salty-Na^+ , sour-H^+, sweet-?, bitter>50 alkaloid receptors, umami-mGluR4

Gustatory compensation and contrast

- When we use sugar for coffe to diminish bitter taste of coffe, we talk about gustatory compensation.
- When we feel more intensive taste of sour in case of eating lemon after sweet think, we talk about gustatory contrast.

Substances changing the sense of taste

- Peripheral or central etiology
- Basic therapy in the treatment of abusus of alcohol and other drugs when we give some substances which trigger very unpleasant taste and finally vomiting
- Patient get accustomed to this situatiom - the gustatory aversion

Disorders of the sense of taste

- Ability for the sense of taste are genetically encoded
- Ageusia – person does not have the sense of taste for some specific substance but other people have very strong sensitivity for this substance
- E.g. taste of sweet-fennel derivate of urea – without any taste x very bitter taste

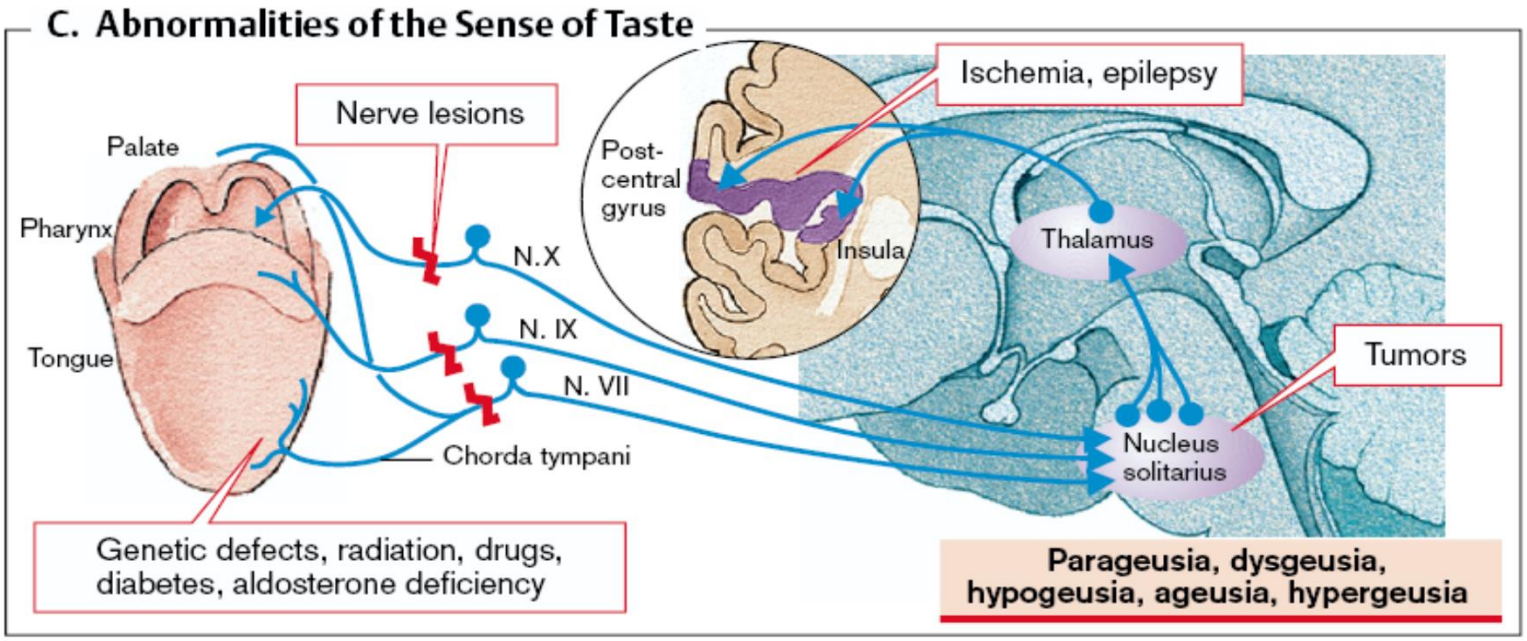
Disorders of the sense of taste

- Hypogeusia – decrease ability of the sense of taste or absence of the sense of taste
- Dysgeusia- unpleasant taste
- Based on different disorders including the disorders of gustatory pathways
- Cover of the tongue, strictures, scars after chemical damage
- Damage of gustatory fibres from the 2/3 of tongue in front of part leads also into damage of other function of n. intermediofacialis – absence of inervation of facial muscles, disturbances in saliva production by salivatory glands
- The reason is otogenic infection or trauma or tumor in canalis n. facialis

Disorders of the sense of taste

- Iritation of cortex part of the sense of smell also causes taste pseudohalucination.

Patophysiology of the sense of taste



Disorders causing the damage of the sense of smell and taste

- But see: olfactory vs. trigeminal irritation
- 1.Neurologic disroders
  - Idiopatic paresis of n. facialis
  - Skull fractures
  - Sclerosis multiplex
  - Parkinsons disease

Disorders causing the damage of the sense of smell and taste

- 2. Endocrine disease
  - Insuficience of suprarenal glands
  - Panhypopituitarismus
  - Cushing dieasea
  - Hypothyroidism
  - Diabetes mellitus
  - Turner sy
  - Kallman sy

Disorders causing the damage of the sense of smell and taste

- 3. Local disorders
  - Sjogren sy
  - Nasal polyps
  - Allergic rhinitis
  - Sinusitis
  - Radiotherapy

Disorders causing the damage of the sense of smell and taste

- 4. Virus infection
  - Acute hepatitis
  - Influenza

Disorders causing the damage of the sense of smell and taste

- 5. Other conditions
  - Tumor diseases
  - Chronic renal insuficience
  - Liver cirhosis
  - Insuficient uptake of vit. B12
  - After laryngectomy

Disorders causing the damage of the sense of smell and taste

- 6. Occupational exposition
  - Amoniac
  - Benzen
  - Formaldehyde

Anorexia

- Psychogenic (stress)
- Psychiatric diagnose like anorexia nervosa
- Diseases affecting stomach, intestine, e.g. Stomach carcinoma- aversion against meat, carcinoma of large intestine, acute hepatitis
- Severe infection, decompensation of cardial insuficience, diabetes decompensation, Addison disease, hyperparathyreosis, alcohol abuse, drug abuse, radiotherapy, treatment – cytostatics,digitalis

Increased apetite

- hyperthyreoidism
- Onset of diabetes
- Malabsorption
- Psychogenic causes

In human we should include...

...as a special type of smell sense:
chemotaxis...

Conclusion

- Disorders of the sense of smell and taste are not rare diseases
- Can lead to change in diet of the patient
- Can lead to carence of proteins, starches, fat and vitamins etc.
- Dysbalance of the sense of taste is ussually caused by disturbance of the sense of smell

Thank you for your attention!

Bon apetite!